DESCRIPTION

COMPONENT PLACING HEAD AND ORIGIN DETECTION METHOD OF COMPONENT PLACING HEAD

Technical Field

The present invention relates to a component placing head for holding a plurality of components by a plurality of component holding members and mounting the components on a circuit board and to an origin detection method for the elevating operation of the component holding members.

Background Art

In recent years, the electronic equipment market has earnestly demanded the downsizing and the functional improvement of various electronic equipment with built-in component-mounted boards formed by placing and mounting a plurality of electronic components as components on a circuit board. Therefore, it is required to carry out high-density mounting (or placement) and high-accuracy mounting (or placement) of the electronic components in forming the component-mounted board. It is further demanded to reduce the production cost of component-mounted boards. For example, it is additionally demanded to

improve the productivity per unit area of the component-mounted boards, i.e., the productivity per unit area in mounting the electronic components.

Such a component-mounted board is manufactured by placing the plurality of electronic components on the circuit board and thereafter heating the circuit board on which the electronic components are placed in a reflow manner for the mounting of the electronic components placed on the circuit board. Such a manufacturing process is called a component mounting process (or component-mounted board producing process), which is categorized roughly into a component placing process and a reflow process. The component placing process is carried out by an electronic component placing apparatus provided with a component placing head that sucks and holds a plurality of electronic components and places them on a circuit board.

Fig. 4 shows a sectional view of a head section 500 that is one example of the component placing head employed in such a conventional electronic component placing apparatus (refer to, for example, Japanese unexamined Patent Publication No. 2000-40900), and the structure of the head section 500 will be described with reference to Fig. 4.

As shown in Fig. 4, the head section 500 is provided with a suction nozzle 502 that is one example of

the component holding member for releasably holding an electronic component 501 such as a chip component, a shaft section 510 that is one example of the shaft section detachably equipped with this suction nozzle 502, an elevation unit 520 for moving up and down the suction nozzle 502 equipped for the shaft section 510 via this shaft section 510 and a rotating unit 530 for rotating the suction nozzle 502 around its axis of rotation (its axial center of rotation) via the shaft section 510.

Moreover, in order to improve the efficiency of the operation of placing the electronic components 501 on a circuit board by providing the head section 500 with a plurality of suction nozzles 502 capable of individually sucking and holding electronic components 501, the head section 500 is provided with, for example, eight sets of shaft sections 510 and elevation units 520, and the shaft sections 510 and the elevation units 520 are supported by a head frame 540 of the head section 500 so that the shaft sections 510 are arranged in a line (i.e., the suction nozzles 502 are arranged in a line). Moreover, the rotating unit 530 is able to rotate four suction nozzles 502 equipped for mutually adjacent four shaft sections 510. In the head section 500 capable of equipped with eight suction nozzles 502, two rotating units 530 are provided while being supported by the head frame 540, by which the

suction nozzles 502 equipped for the shaft sections 510 are made rotatable.

With regard to the head section 500 having the above-mentioned construction, the detailed structure of the shaft section 510 will be described first. As shown in Fig. 4, each shaft section 510 is provided with a spline shaft 511 that has a nozzle attaching portion 511a, which is one example of the holding member attaching portion capable of detachably equipped with the suction nozzle 502, at its end portion (lower end in the figure). Moreover, the spline shaft 511 is able to rotate around its axis P of rotation by the rotating unit 530 corresponding to this shaft section 510 and elevatable along the axis P of rotation by the corresponding elevation unit 520. In the shaft sections 510, spline shafts 511 are elevatable and rotatable as described above while being supported as the shaft sections 510 by the head frame 540. This support structure will be described by using the partially enlarged schematic view of the shaft section 510 shown in Fig. 5.

As shown in Fig. 5, the shaft section 510 is further provided with a first spline nut 512 (arranged on the upper side in the figure) and a second spline nut 513 (arranged on the lower side in the figure), which are arranged apart from each other along the axis P of rotation of the spline shaft 511, and which are two spline nuts that

elevatably supports the spline shaft 511.

Moreover, as shown in Fig. 5, the first spline nut 512 and the second spline nut 513 are supported via a bearing section 514 and a bearing section 515, respectively, to a shaft frame 541 rotatably around the axis P of rotation together with the spline shaft 511 on the inner periphery of the shaft frame 541 that has a roughly cylindrical shape in the head frame 540. Moreover, a roughly cylindrical outer cylinder collar 516 has its inner peripheral surface bonded to the outer periphery of the first spline nut 512, and the outer periphery of the outer cylinder collar 516 is further rotatably supported on the inner periphery of the shaft frame 541 via another bearing section 517, rotatably supporting the first spline nut 512. Moreover, an outer cylinder collar 518 is similarly bonded to the second spline nut 513 and rotatably supported via another bearing section 519.

With the shaft section 510 having the above-mentioned structure, the spline shaft 511 is elevatable along the axis P of rotation on the inner periphery of the first spline nut 512 and the second spline nut 513 in the shaft section 510, and both the first spline nut 512 and the second spline nut 513 are made rotatable around the axis P of rotation on the inner periphery of the shaft frame 541.

The detailed structure of the rotating unit 530 will be described next. As shown in Fig. 4, the rotating unit 530 is provided with a shaft gear 531 arranged so that the spline shaft 511 penetrates the cylindrical inner portion thereof. Moreover, the shaft gear 531 rotates the first spline nut 512 by the rotation around the axis P of rotation thereof, allowing the spline shaft 511 to be rotated. Further, the rotating unit 530 is provided with a cogged belt 532 engaged with the shaft gear 531, a driving gear 533 engaged with the cogged belt 532, and a rotating drive motor 534 to the end of its driving shaft 534a of which the driving gear 533 is fixed and which is able to rotate the driving shaft 534a in either the forward or reverse direction.

Moreover, as shown in Fig. 5, the shaft gear 531 has its lower end connected to an upper end portion 516a in the figure of the outer cylinder collar 516 bonded to the first spline nut 512 via a ring-shaped coupling 535. Moreover, the shaft gear 531 is supported on the inner peripheral surface of the shaft frame 541 so as to be rotatable around the axis P of rotation via two bearing sections 536 at the upper end and the lower end of its outer peripheral surface and so as not to come in contact with the spline shaft 511. Moreover, a plurality of teeth are continuously provided on the outer peripheral surface

of the shaft gear 531, the inner peripheral surface of the cogged belt 532 and the outer peripheral surface of the driving gear 533 in order to strengthen the mutual engagement.

In this case, relations of planes among the shaft gear 531, the cogged belt 532 and the driving gear 533 will be described here with reference to the schematic explanatory view shown in Fig. 6. As shown in Fig. 6, one driving gear 533 and mutually adjacent four shaft gears 531 are engaged with one another inside one cogged belt 532. That is, by rotatively dividing the driving gear 533 in either the forward or reverse direction by the rotating drive motor 534, the cogged belt 532 is driven to run in the rotational drive direction, allowing the four shaft gears 531 to be concurrently rotated in the rotational drive direction. Moreover, between the shaft gears 531 and between the shaft gear 531 located at the left-hand end in the figure and the driving gear 533, four tension rollers 537 are provided so as to consistently urge the cogged belt 532 toward the inside, consistently applying a constant tension to the cogged belt 532 and keeping a satisfactory engagement relation among the gears.

With the rotating unit 530 having the above-mentioned structure, the spline shafts 511 corresponding to the four shaft gears 531 can be rotated around the axis P

of rotation concurrently in the same rotational direction via the coupling 535 and the first spline nut 512.

The elevation unit 520 will be described next. As shown in Fig. 4, the elevation unit 520 is provided with a ball screw shaft 521 supported by an elevation frame 542 of the head frame 540 rotatably around the axis Q of rotation (the axial center of rotation) thereof arranged roughly parallel to the axis P of rotation of the spline shaft 511. The elevation unit 520 is further provided with an elevation drive motor 522, which is fixed to an upper end portion in the figure of the ball screw shaft 521 and rotates the ball screw shaft 521 in either the forward or reverse direction around the axis Q of rotation, and an elevation nut section 523, which is meshed with the ball screw shaft 521 and is moved up and down along the axis Q of rotation by the rotation of the ball screw shaft 521. Moreover, the elevation unit 520 is further provided with a roughly L-figured elevation bar 524, which has one end fixed to the elevation nut section 523 and is moved up and down in accordance with the ascent and descent of the elevation nut section 523, and the other end of the elevation bar 524 is arranged so as to be placed between two bearing sections 525 attached to an upper portion of the spline shaft 511.

With the above-mentioned structure possessed by

the elevation unit 520, when the elevation nut section 523 is moved up or down by the rotation of the ball screw shaft 521, the elevation bar 524 is moved up or down to push up or push down the spline shaft 511 via the bearing sections 525 by its end portion, allowing the spline shaft 511 to be moved up and down. It is to be noted that the ascent and descent of the elevation bar 524 is guided by an LM guide 526 provided on the elevation frame 542.

Moreover, as a component placing head as described above, there has conventionally been a head section provided with a plurality of suction nozzles that serve as one example of the component holding member arranged in a line. In the head section described above, the efficiency of placing components on a circuit board has been improved by making the suction nozzles concurrently suck and hold a plurality of components. Moreover, during the component placing operation by the head section, the elevating operation of the suction nozzles is to be performed. However, due to the necessity for performing individual elevating operation of the suction nozzles, the head section is provided with elevation units corresponding one to one to the suction nozzles.

Moreover, the head section described above is generally able to individually perform the elevating operation of the suction nozzles by generally performing

the elevating operation of the shaft sections capable of being detachably equipped with a suction nozzle at its end by the respective elevation units (these shaft sections are also provided for the head section while being arranged in a line). Moreover, the elevation units generally employ a mechanism employing a ball screw shaft section and a nut section meshed with it and rotatively drive the ball screw shaft section by rotatively driving the drive motor attached to the ball screw shaft section, thereby moving up and down the nut section and enabling the elevating operation of the shaft section in the state in which it can be moved up and down in synchronization with the ascent and descent of the nut section while being engaged with the nut section.

Next, Fig. 14 shows a schematic explanatory view of the elevation units 410 of the head section 400 described above, and a method for detecting an origin that becomes a reference point of the ascent and descent of each of the elevation units 410 (refer to, for example, Japanese unexamined Patent Publication No. 62-236655) will be described with reference to Fig. 14.

As shown in Fig. 14, the head section 400 is provided with eight elevation units 410, i.e., eight suction nozzles (not shown). Moreover, each of the elevation units 410 is provided with a ball screw shaft

section 411, a nut section 412, a drive motor 413 and an upper end position restricting frame 414 for restricting the upper end position of elevation of the nut section 412.

Moreover, the head section 400 is provided with a control section 409 capable of individually controlling these elevation units 410. Each of the elevation units 410 is further provided with an encoder (not shown) capable of detecting the rotational angle of the drive motor 413 and outputting this detection result to the control section 409.

When detecting the origin in the head section 400 described above, by detecting the rotational angle by the encoder while rotatively driving the drive motor 413 in each of the elevation units 410 and assuming the position of the nut section 412 on the elevating operation axis when the origin of rotation in the rotational direction is detected as the origin (hereinafter referred to as a detection origin), each of the detection origins is set by the control section 409.

It is to be noted that these operations may be executed either individually or concurrently in the elevation units 410. Subsequently, the elevating operation of each of the suction nozzles for the component placing operation is executed in the head section 400 regarding the detection origin thus set as the origin on the actual elevating operation axis (hereinafter referred to as an

axial origin).

Disclosure Of Invention

However, in the head section 500 having the aforementioned structure, the first spline nut 512 and the second spline nut 513 have their outer peripheral surfaces rotatably supported via the bearing section 514 and the bearing section 515, respectively, to the shaft frame 541 in each of the shaft sections 510. Accordingly, there is a problem that the outside diameter dimensions of the bearing sections 514 and 515 are increased by the first spline nut 512 and the second spline nut 513 interposed, and the arrangement interval of the spline shafts 511 arranged in a line cannot be shortened, hindering the downsizing of the head section 500.

Moreover, when the outside diameter dimension of the spline shafts 511 is reduced to solve the above-mentioned problem, it is sometimes difficult to secure the rigidity required for the placement of the electronic component 501. In such a case, it is sometimes the case where the spline shaft 511 is bent by an external force received during the replacement of the suction nozzle 502 to be equipped or in another case, and this also leads to a problem that this arrangement cannot cope with the placement of electronic components that require high-

accuracy positioning.

Moreover, in each of the shaft sections 510, the first spline nut 512, the second spline nut 513, the bearing sections 541 and 515, the outer cylinder collars 516 and 518 and the bearing sections 517 and 519 are individually processed and thereafter assembled. Therefore, it is difficult to make the axes of rotation coincide with the axis P of rotation of the spline shaft 511. In such a case, there is also a problem of displacement due to rotation occurring at the end of the suction nozzle 502 equipped for the nozzle attaching portion 511a of the spline shaft 511.

Moreover, it is also difficult to make the axes of rotation of the mutually connected shaft gear 531, the coupling 535 and the outer cylinder collar 516 coincide with the axis P of rotation for a similar reason, and joint portions of the members receive stress due to the misalignment of the axes of rotation. In such a case, there is also a problem that the rotational accuracy is reduced and this arrangement cannot cope with the placement of electronic components that require high-accuracy positioning.

Moreover, the rotating unit 530 has the structure in which one driving gear 533 and the mutually adjacent four shaft gears 531 are in engagement inside one cogged

belt 532. Therefore, even if a tension is consistently applied to the tension rollers 537, particularly the area of engagement of the cogged belt 532 with two shaft gears 531 out of the four shaft gears 531 is less than that of the shaft gears 531 located at both ends, possibly causing a slip between the two shaft gears 531 and the cogged belt 532. In such a case, there is a problem that influence is exerted on the rotational accuracy of the spline shafts 511, i.e., the rotational accuracy of the suction nozzles 502, and this arrangement cannot cope with the placement of electronic components that require high-accuracy positioning.

On the other hand, the aforementioned origin detection method in the head section 400 does not confirm whether the detection origin actually coincides with the axial origin. Therefore, in the case where, for example, an error occurs during the detection of the origin of rotation by the encoder, there is a problem that the detection origin does not coincide with the axial origin, possibly causing a placement error in the subsequent component mounting operation and failing in executing reliable placing operation. Moreover, there is also a problem that high-accuracy component placement can not be achieved if the situation does not get worse to such an extent that the placement error occurs.

As a method for solving such a problem, it can be considered to provide each of the elevation units 410 individually with a sensor for confirming the position of elevation of each of the nut sections 412 and confirm that the detection origin coincides with the axial origin by each of the sensors.

However, such an origin detection method passes for the case where the head section is provided with one suction nozzle. However, when the head section 400 is provided with eight suction nozzles and further when eight elevation units 410 are provided so as to correspond one to one to the suction nozzles, it is required to provide the elevation units 410 with the respective sensors, i.e., provide the head section 400 with eight sensors in total. Accordingly, there is a problem that the construction of the head section 400 becomes complicated for the origin detection, and this becomes a factor of hindering the downsizing of the head section, failing in suppressing the production cost of the head section 400 low.

Accordingly, the object of the present invention is to solve the aforementioned problems and provide a component placing head and an origin detection method by the component placing head capable of coping with high-accuracy component placing operation on a circuit board by the component placing head that holds a plurality of

components by a plurality of component holding members and places the components on the circuit board, permitting downsizing and improving the productivity per unit area in placing the components.

In order to achieve the aforementioned object, the present invention is constructed as follows.

According to a first aspect of the present invention, there is provided a component placing head comprising:

a plurality of component holding members for releasably holding a plurality of components;

a plurality of shaft sections detachably equipped with each of the component holding members;

elevation units for executing elevating operations of the component holding members;

a rotating unit for executing rotational operation of each of the component holding members for correction of holding postures of components held by the component holding members; and

a head frame that has shaft support sections for supporting the shaft sections and supports the elevation units and the rotating unit, the component placing head being able to place the plurality of components held by the component holding members on a circuit board,

the shaft sections each comprising:

a spline shaft that has a holding member attaching portion for detachably equipping with the component holding member at its end portion and is rotatable around an axis of rotation by the rotating unit, elevatable along the axis of rotation by the elevation unit and arranged so as to penetrate the shaft support section;

a first spline nut and a second spline nut that are arranged apart from each other along the axis of rotation in vicinity of an upper end and a lower end, respectively, of the shaft support section and elevatably support the spline shaft; and

cylindrical members that have inner peripheral portions fixed to outer peripheral portions of the first spline nut and the second spline nut and join the first spline nut to the second spline nut so as to put the spline nuts into an integrated state, and

the cylindrical members being supported in the vicinity of the upper end and the lower end of the shaft support section rotatably around the axis of rotation via two bearing sections, elevatably and rotatably supporting the shaft section by the shaft support section.

According to a second aspect of the present invention, there is provided a component placing head as defined in the first aspect, wherein in each of the shaft sections, the spline shaft and the cylindrical members are

processed cutting so that the axis of rotation of the spline shaft coincides with the axes of rotation of the cylindrical members in a state in which the first spline nut, the second spline nut and the cylindrical members are assembled with the spline shaft.

According to a third aspect of the present invention, there is provided a component placing head as defined in the first aspect, wherein the cylindrical members in each of the shaft sections are integrally formed of:

the first cylindrical member that has a nut fixation portion whose inner peripheral portion is fixed to the outer peripheral portion of the first spline nut and a support portion whose outer peripheral portion is supported by one bearing section of the two bearing sections;

the second cylindrical member that has a nut fixation portion whose inner peripheral portion is fixed to the outer peripheral portion of the second spline nut and a support portion whose outer peripheral portion is supported by the other bearing section of the two bearing sections; and

the cylindrical joint member that join the first cylindrical member to the second cylindrical member, and

a stepped portion is formed between the support portion and the nut fixation portion so that a diameter of

the outer peripheral portion of the support portion is smaller than a diameter of the inner peripheral portion of the nut fixation portion at each of the first cylindrical member and the second cylindrical member.

According to a fourth aspect of the present invention, there is provided a component placing head as defined in the third aspect, wherein the rotating unit comprises:

a transmission gear section whose inner peripheral portion is fixed to the outer peripheral portion of the support portion of either one of the first cylindrical member and the second cylindrical member in each of the shaft sections;

a cogged belt that internally has a plurality of teeth capable of being engaged with the transmission gear section and is engaged with the transmission gear section; and

a rotating drive section that rotatively drives the cogged belt, whereby

the support portion is rotatively driven by rotatively driving the transmission gear section around its axis of rotation via the cogged belt by the rotating drive section in each of the shaft sections, enabling the spline shaft to be rotatably driven via the first spline nut and the second spline nut.

According to a fifth aspect of the present invention, there is provided a component placing head as defined in the fourth aspect, further comprising:

four shaft sections constructed of a first shaft section through a fourth shaft section arranged mutually adjacent in a line as the shaft sections,

wherein the rotating unit comprising:

four transmission gear sections constructed of a first transmission gear section through a fourth transmission gear section attached to the first shaft section to the fourth shaft section, respectively, as the transmission gear sections; and

a first cogged belt engaged with only the first transmission gear section and the third transmission gear section among the four transmission gear sections and a second cogged belt engaged with only the second transmission gear section and the fourth transmission gear section as the cogged belts, and

the rotating drive section comprising one rotating drive shaft section that is engaged with the first cogged belt and the second cogged belt and is able to rotatively drive both the first cogged belt and the second cogged belt.

According to a sixth aspect of the present invention, there is provided a component placing head as

defined in the third aspect or fourth aspect, wherein each of the elevation units comprises:

a ball screw shaft section supported rotatably around its axis of rotation;

a rotating drive section that is fixed to an end portion of the ball screw shaft section and for rotating the ball screw shaft section around the axis of rotation;

an elevation nut section that is meshed with the ball screw shaft section and is elevatable along the axis of rotation center of the ball screw shaft section by the rotation of the ball screw shaft section; and

an engagement member that is fixed to the elevation nut section and engaged with the spline shaft of the corresponding shaft section and is able to move up and down the spline shaft in synchronization with the ascent and descent of the elevation nut section, and

the elevation nut section is elevatable along the axis of rotation in a state in which the rotation of the ball screw shaft section around the axis of rotation is restricted only by the engagement of the engagement member with the spline shaft.

According to a seventh aspect of the present invention, there is provided a component placing head as defined in the first aspect,

wherein the shaft sections are arranged mutually

in a line,

the elevation units are comprised of a plurality of elevation units that correspond one to one to the shaft sections and for moving up and down the shaft sections along the respective axes of rotation,

each of the elevation units comprises:

a ball screw shaft section supported rotatably around its axis of rotation;

a rotating drive section that is fixed to an end portion of the ball screw shaft section and for rotating the ball screw shaft section around the axis of rotation;

an elevation nut section that is meshed with the ball screw shaft section and is elevatable along the axis of rotation of the ball screw shaft section by the rotation of the ball screw shaft section; and

an engagement member that is fixed to the elevation nut section and engaged with the corresponding shaft section and able to move up and down the shaft section in synchronization with the ascent and descent of the elevation nut section,

the component placing head further comprising:

a light transmission unit that is provided with a light-projecting section and a light-receiving section arranged so as to be opposite to each other in a direction along an array direction of the ball screw shaft sections

and able to arrange the elevation nut sections between the light-projecting section and the light-receiving section and able to detect presence or absence of interruption of light by the elevation nut section by receiving the light emitted from the light-projecting section toward the light-receiving section by the light-receiving section;

a plurality of rotational angle detecting sections capable of detecting a rotational angle of the rotating drive section provided for each of the elevation units; and

an origin detection control section is operable to set an origin of elevation of the elevation nut section by detecting the rotational angle by the rotational angle detecting section in each of the elevation units, individually move down the elevation nut sections located in respective set origin positions so that the light emitted from the light-projecting section is received by the light-receiving section without being interrupted, detect the interruption of light emitted from the light-projecting section by the lowered elevation nut section by the light-receiving section in a position where the elevation nut section is lowered from each of the set origins by a prescribed light interruption dimension, thereby confirming the fact that the set origins are origins of elevation to execute the detection of the

origins.

According to a eighth aspect of the present invention, there is provided a component placing head as defined in the seventh aspect, wherein each of the elevation units further comprising:

an overload detecting section capable of detecting overload of the rotating drive section; and

restricting portions that are fixed to the ball screw shaft section while being located apart from each other and for restricting mechanically the upper end position and the lower end position of elevation of the elevation nut section, and

the origin detection control section is operable to reverse the rotational direction of the rotating drive section when the overload of each of the rotating drive sections is detected by the respective overload detection section by moving each of the elevation nut sections to the upper end position of the elevating operation and bringing each of the elevation nut sections in contact with the restricting portion in the upper end position, and detect the rotational angle by the rotational angle detection section in each of the elevation units after the reversing, whereby set the position along the axial center of the elevation nut section when the origin of rotation of the rotating drive section is detected at a first time as the

origin of elevation.

According to a ninth aspect of the present invention, there is provided a component placing head as defined in the seventh aspect, wherein the light-projecting section and the light-receiving section are arranged so that the light emitted from the light-projecting section can be transmitted and received by the light-receiving section in each of positions located apart by the prescribed light interruption dimension downwardly along the axis of rotation of each of the ball screw shaft sections from each of the origins.

According to a tenth aspect of the present invention, there is provided a component placing head as defined in any one of the seventh aspect through ninth aspect, wherein each of the elevation nut sections can consistently interrupt the light emitted from the light-projecting section in the position of elevation of the elevation nut section between each of positions located apart by the prescribed light interruption dimension downwardly along each of the axes of rotation from each of the origins and a lower end position of elevation of the elevation nut section.

According to a eleventh aspect of the present invention, there is provided an origin detection method for a component placing head having:

a plurality of shaft sections that has an end portion provided with a plurality of component holding members for releasably holding components and are arranged in a line;

a plurality of elevation units that correspond one to one to the shaft sections and for moving up and down each of the shaft sections along its axis of rotation, the elevation units being comprised of,

a ball screw shaft section supported rotatably around its axis of rotation,

a rotating drive section that is fixed to an end portion of the ball screw shaft section and for rotating the ball screw shaft section around the axis of rotation,

an elevation nut section that is meshed with the ball screw shaft section and is elevatable along the axis of rotation of the ball screw shaft section by the rotation of the ball screw shaft section, and

an engagement member that is fixed to the elevation nut section and engaged with the corresponding shaft section and able to move up and down the shaft section in synchronization with the ascent and descent of the elevation nut section; and

a light-projecting section and a light-receiving section, which are arranged opposite to each other in a direction along an array direction of the ball screw shaft

sections and are able to arrange each of the elevation nut sections between the light-projecting section and the light-receiving section and are able to detect the presence or absence of the interruption of light by the elevation nut section by receiving the light emitted from the light-projecting section toward the light-receiving section by the light-receiving section, whereby the components held by the component holding members are placed on the circuit board,

the method comprising:

setting an origin of elevation of the elevation nut section by detecting the rotational angle of the rotating drive section in each of the elevation units;

individually moving down the elevation nut sections located in the respective set origin positions so that the light emitted from the light-projecting section is received by the light-receiving section without being interrupted; and

confirming the fact that each of the set origins are origins of elevation by detecting the interruption of light emitted from the light-projecting section by the lowered elevation nut section by the light-receiving section in a position where the elevation nut section is lowered from each of the set origins by a prescribed light interruption dimension to execute the detection of the

origins.

According to a twelfth aspect of the present invention, there is provided an origin detection method for the component placing head defined in the eleventh aspect, wherein,

moving each of the elevation nut sections to an upper end position of its elevating operation,

reversing the rotational direction of the rotating drive section when overload of each of the rotating drive sections is detected at each of the upper end positions, and

detecting the rotational angle of each of the elevation units after the reversing, the position along the axis of rotation of the elevation nut section when the origin of rotation of the rotating drive section is detected at a first time can be set as the origin of elevation.

According to a thirteenth aspect of the present invention, there is provided an origin detection method for the component placing head defined in the eleventh aspect, wherein the light-projecting section and the light-receiving section are arranged so that the light emitted from the light-projecting section can be transmitted and received by the light-receiving section in each of positions located apart by the prescribed light

interruption dimension downwardly along the axis of rotation of each of the ball screw shaft sections from each of the origins.

According to a fourteenth aspect of the present invention, there is provided an origin detection method for the component placing head defined in any one of the eleventh aspect through thirteenth aspect,

wherein each of the elevation nut sections can consistently interrupt the light emitted from the light-projecting section in the position of elevation of the elevation nut section between each of positions located apart by the prescribed light interruption dimension downwardly along the axis of rotation from each of the origins and a lower end position of elevation of the elevation nut section, and

movement of each of the component holding members in a direction along a surface of the circuit board is inhibited in the state in which light is interrupted.

According to the first aspect of the present invention, the cylindrical member is fixed to the outer peripheral portions of the first spline nut and the second spline nut, which are arranged apart from each other in the vicinity of the upper end and the lower end of the shaft support section at the shaft sections of the component placing head and elevatably support the spline shaft along

the axis of rotation thereof. With this arrangement, the two spline nuts of the first spline nut and the second spline nut can be joined to each other and put into an integrated state.

Furthermore, the cylindrical member is supported in the vicinity of the upper end and the lower end of the shaft support section rotatably around the axis of rotation via the two bearing sections. With this arrangement, the two spline nuts put in the above-mentioned integrated state can be supported rotatably around the axis of rotation via the two bearing sections to the shaft support section. That is, the two spline nuts can be rotatably supported by the two bearing sections, and the amount of the bearing sections to be provided for supporting the spline nuts can be reduced in the bearing sections.

Therefore, the bearing sections can easily be assembled in the component placing head, and the production cost of the component placing head can be reduced. In addition, since the amount of the bearing sections to be provided can be reduced, the rotational center positional alignment of the axis of rotation of each of the spline shafts with the axis of rotation of each of the bearing sections (i.e., also the axis of rotation of the cylindrical member) can be facilitated. The amount of displacement of the axis of rotation due to the rotation of

the component holding member equipped for each of the shaft sections can be reduced, and the rotational accuracy can be improved. Accordingly, there can be provided a component placing head capable of coping with the component placement that requires high-accuracy component positioning.

According to the second aspect of the present invention, the spline shaft and the cylindrical member are machined so that the axis of rotation of the spline shaft coincides with the axis of rotation of the cylindrical member in the state in which the spline shaft, the first spline nut, the second spline nut and the cylindrical member are assembled into an integrated body before each of the shaft sections are assembled and attached to the component placing head. With this arrangement, the above-mentioned axes of rotation can be made to roughly coincide with one another with high accuracy. Therefore, the component placing head, which is assembled by inserting the shaft sections into the shaft frame while being rotatably supported, can cope with the component placement that require high-accuracy component positioning.

According to the third aspect of the present invention, in each of the shaft sections, the cylindrical member is integrally formed of: the first cylindrical member provided with the nut fixation portion whose inner peripheral portion is fixed to the outer peripheral portion

of the first spline nut arranged in the vicinity of either one of the upper end and the lower end of the shaft support section and the support portion supported by one bearing section out of the two bearing sections by its outer peripheral portion; the second cylindrical member provided with the nut fixation portion whose inner peripheral portion is fixed to the outer peripheral portion of the second spline nut arranged in the vicinity of the other one and the support portion is supported by the other bearing section out of the two bearing sections by its outer peripheral portion; and the cylindrical joint member for joining the first cylindrical member to the second cylindrical member, and the stepped portion is formed between the support portion and the nut fixation portion so that the diameter of the outer peripheral portion of the support portion is smaller than the diameter of the inner peripheral portion of the nut fixation portion in each of the first cylindrical member and the second cylindrical member. With this arrangement, the diameter of the inner peripheral portion of each of the bearing sections can be made smaller than the diameter of the outer peripheral portion of each of the spline nuts.

As described above, when the diameter of the inner peripheral portion of the bearing section can be reduced, the outside diameter of each of the shaft sections

can be reduced, and the arrangement interval between the spline shafts provided for the component placing head can be narrowed, allowing a downsized component placing head to be provided. In such a case, the component placing apparatus provided with the downsized component placing head can also be downsized, and there can be provided a component placing head capable of improving the productivity per unit area in placing components by reducing the installation area of the component placing apparatus.

Conversely, when the outside diameter of each of the shaft sections is not reduced, the outside diameter of the spline shaft can be increased without changing the outside diameter of the shaft section, and the rigidity of the spline shaft can be improved. In such a case, for example, even when an external force is applied to the spline shaft during the replacement of the component holding member or the like, the occurrence of displacement of the axis of rotation of the spline shaft can be prevented by the rigidity, and a component placing head that has higher rotational accuracy can be provided.

According to the fourth aspect of the present invention, in the rotating unit of the component placing head, dissimilarly to the conventional case where the transmission gear section is attached to the shaft section

via the coupling, the transmission gear section is attached to the shaft section in the state in which the inner peripheral portion thereof is directly fixed to the outer peripheral portion of the support portion of either one of the first cylindrical member and the second cylindrical member. With this arrangement, the misalignment of the axis of rotation of the transmission gear section with respect to the axis of rotation of the spline shaft due to the existence of the coupling can be reduced. Therefore, the concentricity of the axes of rotation of the transmission gear section and the spline shaft can be improved, and there can be provided a component placing head of which the rotational accuracy is improved.

According to the fifth aspect of the present invention, in the rotating unit, dissimilarly to the conventional case where the four transmission gear sections are engaged with one another by one cogged belt, the rotating unit is provided with the two cogged belts of the first cogged belt and the second cogged belt. The first cogged belt is engaged with the first transmission gear section and the third transmission gear section, while the second cogged belt is engaged with the second transmission gear section and the fourth transmission gear section. With this arrangement, the areas of engagement of the four transmission gear sections can be uniformed in the state in

which the areas of engagement of the cogged belts with respect to the respective transmission gear sections is sufficiently secured. With this arrangement, the deviation in the rotational accuracy, which has occurred due to the deviation in the area of engagement, can be canceled. In addition, by sufficiently securing the area of engagement, there can be provided a component placing head capable of reliably rotating each of the transmission gear sections and rotating each of the component holding members with high accuracy.

According to the sixth aspect of the present invention, the construction, in which the elevation nut section can be moved up and down along the axial center by the fact that the rotation of the ball screw shaft section around the axis of rotation is restricted only by the engagement between the engagement member and the spline shaft in each of the elevation units of the component placing head, can be achieved by improving the rigidity (i.e., strength) with the outside diameter of the spline shaft formed large by the support structure with the outside diameter of the bearing section maintained. Therefore, the restricting member (e.g., LM (Line Motion) guide), which has been needed for receiving the rotation moment transmitted from the elevation nut section to the spline shaft via the engagement member in a support

structure such that the outside diameter of the spline shaft cannot be formed large as in the conventional component placing head, can be made unnecessary in the component placing head of the aforementioned sixth aspect. With this arrangement, there can be provided a further downsized component placing head capable of reducing the dimension between the axis of rotation of the spline shaft and the axis of rotation of the ball screw shaft section by the needlessness of the conventional restricting member and improving the productivity per unit area.

According to the seventh aspect or the eleventh aspect of the present invention, instead of detecting the rotational angle of each of the rotating drive sections using each of the rotational angle detecting sections provided for the component placing head, setting the origin of elevation of each of the elevation nut sections and thereafter executing the component placing operation by moving up and down each of the component holding members in the component placing head directly using the set origins without confirming the set origins, it is confirmed whether or not these set origins actually coincide with the origins of elevation. Therefore, even if a malfunction (setting error) occurs during the setting of each of the origins, the setting error can surely be detected, and the placement error due to the fact that the set origin does not coincide

with the origin of elevation can be prevented from occurring in advance during the subsequent component placing operation by the component placing head, and reliable origin detection can be performed.

Moreover, the above-mentioned origin detection can be achieved by providing the component placing head with only one light transmission unit, which is provided with the light-projecting section and the light-receiving section arranged so as to be opposite to each other in the direction along the array direction of the ball screw shaft sections and is able to arrange each of the elevation nut sections between the light-projecting section and the light-receiving section and able to detect the presence or absence of the interruption of the light by the elevation nut section by receiving the light emitted from the light-projecting section toward the light-receiving section by the light-receiving section.

That is, by individually moving down each of the elevation nut sections located in the respective set origin positions so that the light emitted from the light-projecting section of the provided one light transmission unit is received by the light-receiving section without being interrupted and detecting the interruption of the light emitted from the light-projecting section by the lowered elevation nut section by the light-receiving

section in the position lowered by the prescribed light interruption dimension from each of the set origins, it can be confirmed that each of the set origins is the origin of the elevation, and the detection of each of the origins can be performed.

Therefore, even if a plurality of component holding members are provided as in the case of the aforementioned component placing head, the origin can be confirmed by the provision of one light transmission unit as the component placing head without providing each of the elevation units with a unit for confirming the origin. Accordingly, there can be provided a component placing head capable of executing reliable origin detection with a simpler construction, and the production cost can also be suppressed low. As a result, there can be provided a component placing head capable of achieving the downsizing of the component placing head while being able to cope with the high-accuracy component placing operation and improving the productivity per unit area during the component placing.

Moreover, the light transmission unit is able to detect whether or not the light emitted from the light-projecting section is directly interrupted by the elevation nut section, so that the construction of the component placing head can be simplified providing no special light shield plate (e.g., DOG etc.) for the interruption of the

light.

According to the eighth aspect or the twelfth aspect of the present invention, in the component placing head, each of the elevation units is further provided with the overload detecting section capable of detecting the overload of the rotating drive section and each of the restricting portions that are fixed to the ball screw shaft section while being located apart from each other and mechanically restricts the upper end position and the lower end position of elevation of the elevation nut section. By reversing the rotational direction of the rotating drive section when the overload of each of the rotating drive sections is detected in each of the overload detection sections by moving each of the elevation nut sections to the upper end position of the elevating operation and bringing each of the elevation nut sections in contact with the restricting portion in the upper end position in the origin detection control section and detecting the rotational angle by the rotational angle detection section in each of the elevation units after the reversing, the position of the elevation nut section along the axial center when the origin of rotation of the rotating drive section is detected at the first time can be set as the origin of the elevation. With this arrangement, each of the origins can be set by using each of the rotational

angle detection sections and each of the overload detection sections. Therefore, in addition to the effects of the seventh aspect or the eleventh aspect, each of the origins can be detected with the simple construction of each of the rotational angle detection sections and each of the overload detection sections providing the component placing head with neither complicated mechanism nor unit for the detection of each of the origins.

According to the ninth aspect or the thirteenth aspect of the present invention, the light-projecting section and the light-receiving section are arranged so that the light emitted from the light-projecting section can be transmitted and received by the light-receiving section in each of the positions located apart by the prescribed light interruption dimension downwardly along the axial center of each of the ball screw shaft sections from each of the origins. With this arrangement, by confirming the interruption of the light emitted from the light-projecting section by the lowered elevation nut section in the position in which the elevation nut section is lowered from the set origin by the prescribed light interruption dimension, it can be confirmed that the set origin is the origin of the elevation, and the detection of the origin can be executed reliably and correctly.

According to the tenth aspect or the fourteenth

aspect of the present invention, each of the elevation nut sections can consistently interrupt the light emitted from the light-projecting section in the position of elevation of the elevation nut section between each of the positions located apart by the prescribed light interruption dimension downwardly along the axial center from each of the origins and the lower end position of elevation of the elevation nut section. With this arrangement, when the interruption of light is detected by the light transmission unit, by inhibiting the movement of the main body of the component placing head along the surface of the circuit board, there can be prevented the interference of the component holding members with the constituent members of the electronic component placing apparatus provided with the above-mentioned component placing head and the other components placed on the circuit board. That is, in the component placing head, the detection of light by the light transmission unit can be used as interference prevention interlock of each of the component holding members in addition to the use thereof for the origin detection. This obviates the need for providing the component placing head with a special sensor or the like for providing the above-mentioned interlock and allows the construction of the component placing head to be made simpler.

Brief Description Of Drawings

These and other aspects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view of a head section according to a first embodiment of the present invention;

Fig. 2 is a partially enlarged schematic sectional view of a shaft section in the head section of Fig. 1;

Fig. 3 is a schematic explanatory view showing the relation of engagement among driving gears, shaft gears and cogged belts in a rotating unit of the head section of Fig. 1;

Fig. 4 is a sectional view of a conventional head section;

Fig. 5 is a partially enlarged schematic sectional view of a shaft section in the conventional head section;

Fig. 6 is a schematic explanatory view showing the relation of engagement among a driving gear, shaft gears and a cogged belt in a rotating unit of the conventional head section;

Fig. 7 is a sectional view of part of a head

section according to a modification example of the first embodiment;

Fig. 8 is a schematic sectional view of a head section according to a second embodiment of the present invention;

Figs. 9A, 9B, 9C, and 9D are schematic explanatory views showing the origin detecting operation of each of elevation nut sections in the head section of Fig. 8, where Fig. 9A shows an initial state at the start of the origin detecting operation, Fig. 9B shows a state in which one elevation nut section is moved up to the upper end position of the elevation thereof, Fig. 9C shows a state in which the detection origin is set in each of the elevation nut sections, and Fig. 9D shows a state in which one elevation nut section is moved down to the optical axis position of a light transmission unit to confirm whether or not the detection origin coincides with the axial origin;

Figs. 10A, 10B, and 10C are schematic explanatory views (also views in the direction of arrow A of the head section of Figs. 9A through 9D) showing the position of elevation of the elevation nut section during the origin detecting operation in each of the head sections of Fig. 8, where Fig. 10A shows a state in which the elevation nut section is located at the detection origin, Fig. 10B shows a state in which the interruption of light is detected by

the light transmission unit, and Fig. 10C shows a state in which the elevation nut section is further lowered from the state of Fig. 10B;

Fig. 11 is a schematic explanatory view showing the height position of elevation of each of the elevation nut sections in the head section of Fig. 8;

Fig. 12 is a flowchart showing the procedure of the origin detecting operation in the head section of Fig. 8;

Fig. 13 is a flowchart showing the procedure of the origin detecting operation in the head section of Fig. 8; and

Fig. 14 is a schematic explanatory view showing the origin detecting operation in a conventional head section.

Best Mode for Carrying Out the Invention

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

Embodiments of the present invention will be described in detail below with reference to the drawings.

(First Embodiment)

Fig. 1 shows a sectional view of a head section

100 that is one example of the component placing head according to the first embodiment of the present invention.

As shown in Fig. 1, the head section 100 is provided with a suction nozzle 2 that is one example of the component holding member for releasably sucking and holding an electronic component 1 such as a chip component as one example of the component. Although not shown, this head section 100 is used while being equipped for an electronic component placing apparatus for placing the electronic component 1 on a circuit board held on a machine base. The head section 100 is movably supported roughly parallel to the surface of the circuit board by, for example, an X-Y robot above the machine base and is able to execute the component placing operation of making the suction nozzle 2 of the head section 100 releasably hold the electronic component 1, thereafter aligning in position the placement position of the electronic component 1 on the circuit board with the held electronic component 1 and moving down the suction nozzle 2 to place the electronic component 1 in the placement position of the circuit board. It is to be noted that the positional alignment is also executed in the head section 100 by rotatively moving the suction nozzle 2 around an axis of rotation (axial center) thereof that is the axial center thereof (i.e., rotation by an angle of θ) in addition to the movement of the head section 100 itself

by the X-Y robot. That is, the suction nozzle 2 is able to elevatably move and rotatively move in the head section 100.

The structure of the above-mentioned head section 100 will be described in detail. As shown in Fig. 1, the head section 100 is provided with a shaft section 10 that is one example of a shaft section to be detachably equipped for the suction nozzle 2, an elevation unit 20 for moving up and down the suction nozzle 2 equipped for the shaft section 10 via this shaft section 10 and a rotating unit 30 for rotating the suction nozzle 2 around the axis of rotation thereof (i.e., rotating it by an angle of θ) via the shaft section 10.

Moreover, in the electronic component placing apparatus equipped with the above-mentioned head section 100, there is often used a technique for increasing the amount of electronic components 1 that can be held at a time by a plurality of suction nozzles 2 equipped for the head section in order to improve the placement efficiency by reducing the time required for placing the electronic component 1 on the circuit board. The head section 100 of the present first embodiment is also able to be equipped with eight suction nozzles 2 as one example. That is, the head section 100 is provided with eight sets of shaft sections 10 and elevation units 20. The shaft sections 10 are arranged at a constant interval pitch in a line (i.e.,

the suction nozzles 2 equipped for the shaft sections 10 are arranged at the constant interval pitch in a line), and the elevation units 20 are arranged in a line so as to correspond one to one to the respective shaft sections 10. Moreover, the eight sets of shaft sections 10 and elevation mechanisms 20 are supported by a head frame 40 provided for the head section 100 in the above-mentioned arrangement. Moreover, the rotating unit 30 is able to rotate the four suction nozzles 2 equipped for the mutually adjacent four shaft sections 10. In the head section 100 capable of being equipped with eight suction nozzles 2, two rotating units 30 are provided while being supported by the head frame 40.

(Regarding the Shaft Section)

With regard to the head section 100 having the above-mentioned construction, the detailed structure of the shaft section 10 will be described first. It is to be noted that the eight shaft sections 10 provided for the head section 100 have similar structures. Therefore, in the following description of the structure of the shaft section 10, one shaft section 10 out of these shaft sections will be described unless specially mentioned.

As shown in Fig. 1, each of the shaft sections 10 is provided with a spline shaft 11, at the end portion of which (lower end in the figure) a nozzle attaching portion

11a that is one example of the holding member attaching portion detachably equipped with the suction nozzle 2 is formed. Moreover, in order to make rotatable the suction nozzle 2 equipped for the nozzle attaching portion 11a via the spline shaft 11, the spline shaft 11 is made rotatable around the axis R of rotation thereof (being also the axial center of the spline shaft 11) by the corresponding rotating unit 30. Moreover, in order to similarly make the equipped suction nozzle 2 elevatable via the spline shaft 11, the spline shaft 11 can be moved up and down along the axis R of rotation by the corresponding elevation unit 20.

As described above, in a state in which this spline shaft 11 is rotatable and elevatable in the shaft section 10, the shaft section 10 is supported by the head frame 40. Next, the support structure of this shaft section 10 will be described with reference to the partially enlarged schematic view of the shaft section 10 shown in Fig. 2.

As shown in Fig. 2, the shaft section 10 is further provided with a first spline nut 12 (arranged on the upper side in the figure) and a second spline nut 13 (arranged on the lower side in the figure), which have a roughly cylindrical shape and are arranged apart from the spline shaft 11 along the axis R of rotation of the spline shaft 11 so that the inner peripheral surface thereof is

brought in contact with the outer peripheral surface of the spline shaft 11, and which are two spline nuts for elevatably supporting the spline shaft 11.

Moreover, as shown in Fig. 2, the shaft section 10 is further provided with a first outer cylinder collar 14 that is one example of a first cylindrical member, which has a roughly cylindrical shape and the inner peripheral surface of which has a first nut fixation portion 14a that is one example of a nut fixation portion fixed to the outer peripheral surface (outer peripheral portion) of the first spline nut 12, and a similar second outer cylinder collar 15 that is one example of a second cylindrical member, which has a roughly cylindrical shape and the inner peripheral surface of which has a second nut fixation portion 15a that is one example of a nut fixation portion fixed to the outer peripheral surface (outer peripheral portion) of the second spline nut 13.

Moreover, as shown in Fig. 2, a stepped portion 14c is formed on the first outer cylinder collar 14 so that the diameter of the upper side of the first nut fixation portion 14a is reduced at the upper end of the first nut fixation portion 14a. Moreover, the outer peripheral surface (assumed to be the first support portion 14b that is one example of the support portion) of the portion where the diameter of this stepped portion 14c is formed small is

rotatably supported via a bearing section 51 on the inner peripheral surface of the shaft frame 41 (one example of the shaft support section) that has a roughly cylindrical shape provided for the head frame 40. Moreover, a stepped portion 15c is formed at the second outer cylinder collar 15 so that the diameter on the lower side in the figure of the second nut fixation portion 15a is reduced at the lower end in the figure of the second nut fixation portion 15a. Moreover, the outer peripheral surface (assumed to be a second support portion 15b that is one example of the support portion) of the portion where the diameter of this stepped portion 15c is formed small is rotatably supported via a bearing section 52 on the inner peripheral surface of the shaft frame 41.

As described above, the first spline nut 12 and the second spline nut 13 are arranged apart from each other. Therefore, as shown in Fig. 2, the first spline nut 12 and the bearing section 51 are arranged in the vicinity of the upper end in the figure of the shaft frame 41, while the second spline nut 13 and the bearing section 52 are arranged in the vicinity of the lower end in the figure of the shaft frame 41.

Moreover, as shown in Fig. 2, the first nut fixation portion 14a and the outer peripheral surface of the first spline nut 12 are fixed to each other so that the

lower portion on the outer peripheral surface of the first spline nut 12 is partially exposed from the first nut fixation portion 14a of the first outer cylinder collar 14. Likewise, the second nut fixation portion 15a and the outer peripheral surface of the second spline nut 13 are fixed to each other so that the upper portion on the outer peripheral surface of the second spline nut 13 is partially exposed from the second nut fixation portion 15a of the second outer cylinder collar 15. Further, the shaft section 10 is provided with an intermediate collar 16, which is one example of a cylindrical joint member having a roughly cylindrical shape and has its roughly cylindrical inner peripheral surface bonded to the exposed outer peripheral surfaces of the first spline nut 12 and the second spline nut 13.

It is to be noted that the diameter (outside diameter) of the outer peripheral surface of each of the first spline nut 12 and the second spline nut 13, the diameter (inside diameter) of the inner peripheral surface (inner peripheral portion) of the first nut fixation portion 14a of the first outer cylinder collar 14, the diameter (inside diameter) of the inner peripheral surface (inner peripheral portion) of the second nut fixation portion 15a of the second outer cylinder collar 15 and the diameter (inside diameter) of the inner peripheral surface

of the intermediate collar 16 are formed so as to have approximately same dimension. Further, both end portions in the vertical direction of the intermediate collar 16, which is fixed to the outer peripheral surfaces of the first spline nut 12 and the second spline nut 13, are connected to the end portions of the first outer cylinder collar 14 and the second outer cylinder collar 15.

Moreover, in the first outer cylinder collar 14, the stepped portion 14c is formed so that the diameter of the outer peripheral surface of the first support portion 14b is approximately equal to the diameter of the inner peripheral surface of the first nut fixation portion 14a (i.e., the diameter of the outer peripheral surface of the first spline nut 12) or preferably smaller than the diameter of the inner peripheral surface (e.g., smaller by a dimensional range of about 1 mm to the thickness dimension of the first spline nut 12). Moreover, in the second outer cylinder collar 15, the stepped portion 15c is similarly formed so that the diameter of the outer peripheral surface of the second support portion 15b is approximately equal to the diameter of the inner peripheral surface of the second nut fixation portion 15a (i.e., the diameter of the outer peripheral surface of the second spline nut 13) or preferably smaller than the diameter of the inner peripheral surface (e.g., smaller by a

dimensional range of about 1 mm to the thickness dimension of the second spline nut 13). Moreover, a gap is provided between the inner peripheral surface of the shaft frame 41 and the outer peripheral surfaces of the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16, the gap assuring no contact between them.

In the head section 100 of the present first embodiment, the components are formed so that, for example, the outside diameter of the spline shaft 11 is 8 mm, the outside diameter of the (first and second) spline nuts 12 and 13 is 15 mm, the diameter of the outer peripheral surface of the (first and second) nut fixation portions 14a and 15a of the (first and second) outer cylinder collars 14 and 15 is 18 mm, the diameter of the outer peripheral surface of the (first and second) support portions 14b and 15b is 12 mm and the outside diameter of the bearing sections 51 and 52 is 21 mm. Moreover, the first spline nut 12 and the second spline nut 13 are arranged apart from each other at a distance of 50 mm between the center positions thereof and at a distance of 25 mm by the dimension between the end portions thereof in the direction along the axis R of rotation.

Moreover, the first spline nut 12, the second spline nut 13, the first outer cylinder collar 14, the

second outer cylinder collar 15 and the intermediate collar 16 are bonded together in the above-mentioned relations of arrangement and configuration. With this arrangement, the first spline nut 12 and the second spline nut 13 are put in an integrated state while being joined together via the intermediate collar 16. Also, the first spline nut 12 and the second spline nut 13, which are put in the integrated state, are rotatably supported on the inner peripheral surface of shaft frame 41 via the bearing section 51 at the first support portion 14b of the first outer cylinder collar 14 and via the bearing section 52 at the second support portion 15b of the second outer cylinder collar 15, respectively. In the present first embodiment, the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 serve as one example of the cylindrical member that join the first spline nut 12 and the second spline nut 13 together and put the same into the integrated state. The first spline nut 12 and the second spline nut 13 are arranged in the inner cylindrical portion of the cylindrical member, and the outer peripheral surfaces (portions) thereof are fixed to the inner peripheral surface (portion) of the cylindrical member.

Therefore, with the shaft section 10 having the above-mentioned structure, the spline shaft 11 can move up and down along the axis R of rotation inside the first

spline nut 12 and the second spline nut 13 in the shaft section 10, and the spline shaft 11 is rotatable around the axis R of rotation together with the first spline nut 12 and the second spline nut 13 and further with the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16.

There is accepted the case where the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are originally formed as an integrated body instead of the case where the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are formed as separate components and thereafter assembled together into the integrated body. The above is because the first spline nut 12 and the second spline nut 13 can be joined together into an integrated body even in the above-mentioned case.

(Regarding the Rotating Unit)

Next, the detailed structure of the rotating unit 30 will be described next. As shown in Fig. 1, the rotating unit 30 is also provided with a shaft gear 31 that is one example of the transmission gear section, which has a roughly cylindrical configuration and is arranged so that the spline shaft 11 penetrates through the inside thereof, and on which the outer peripheral surface of which a plurality of teeth 31a are formed. Moreover, the shaft

gear 31 is arranged so that the axis of rotation thereof roughly coincides with the axis R of rotation of the spline shaft 11 and able to rotate the spline shaft 11 around the axis R of rotation by rotating the first spline nut 12 and the second spline nut 13 put in the integrated state by being rotated around the axis of rotation thereof.

Further, the rotating unit 30 has a cogged belt 32 on which inner peripheral surface a plurality of teeth 32a capable of being engaged with the teeth 31a of the shaft gear 31 and is further provided and which engaged with the shaft gear 31, a driving gear 33 on which a plurality of teeth 33a capable of being engaged with the teeth 32a of the cogged belt 32 are formed, and a rotating drive motor 34 that is provided with the driving gear 33 fixed to the end of its driving shaft 34a (one example of the rotating drive shaft) and is able to rotate the driving shaft 34a in either the forward or reverse rotational direction. It is to be noted that the driving gear 33 and the rotating drive motor 34 serve as one example of the rotating drive section that drives the cogged belt 32 to make the same rotate (or run) in the first embodiment.

Moreover, as shown in Fig. 2, the first support portion 14b of the first outer cylinder collar 14 is extended upward in the figure with its diameter maintained, and the extended portion of the first outer cylinder collar

14 is rotatably supported by the shaft frame 41 via the bearing section 53 by the outer peripheral surface of an upper support portion 14d that is the end portion of the extended portion. Moreover, a portion of the outer peripheral surface placed between the bearing section 51 and the bearing section 53 at the extended portion of the first outer cylinder collar 14 is a gear fixation portion 14e (also the extended portion of the first support portion 14b), and the inner peripheral surface of the shaft gear 31 is bonded and fixed to this gear fixation portion 14e. At the gear fixation portion 14e, a space capable of juxtaposing two shaft gears 31 is secured along the axis R of rotation of the spline shaft. However, in Fig. 2, the shaft gear 31 is fixed to the upper portion in the figure of the gear fixation portion 14e. Moreover, Fig. 2 shows the case where the shaft gear 31 is fixed to the lower portion of the gear fixation portion 14e by the imaginary lines in the figure. Moreover, a gap is provided between the inner peripheral surface of the gear fixation portion 14e of the first outer cylinder collar 14 and the outer peripheral surface of the spline shaft 11, the gap assuring no contact between them. As described above, with the shaft gear 31 fixed to the first outer cylinder collar 14 at the gear fixation portion 14e, it is possible to rotate the first outer cylinder collar 14 by rotating the shaft

gear 31 and further rotate the spline shaft 11 around the axis R of rotation by rotating the first spline nut 12 and the second spline nut 13 put in the integrated state around the axis R of rotation.

In this case, the relation in plane among the shaft gears 31, the cogged belts 32 and the driving gears 33 will be described here with reference to the schematic explanatory view shown in Fig. 3.

As shown in Fig. 3, the head section 100 is provided with two rotating units 30. Eight shaft gears 31, which are arranged mutually adjacently at specified intervals in a line, are grouped into groups of four on the left-hand side and four on the right-hand side in the figure, and the groups of the shaft gears 31 belong to the respective rotating units 30. It is to be noted that the two rotating units 30 are grouped into the rotating unit 30 located on the left-hand side in the figure and the rotating unit 30 located on the left-hand side in the figure. However, since the rotating units have similar structures, only the rotating unit 30 located on the left-hand side in the figure will be explained as a representative in the following description.

As shown in Fig. 3, in the rotating unit 30 located on the left-hand side in the figure, the four shaft gears 31 are arranged at specified intervals in a line.

The shaft gears 31 are assumed to be constituted of a first shaft gear 31-1 (one example of the first transmission gear section), a second shaft gear 31-2 (one example of the second transmission gear section), a third shaft gear 31-3 (one example of the third transmission gear section) and a fourth shaft gear 31-4 (one example of the fourth transmission gear section) in order from the left-hand side toward the right-hand side in the figure. Moreover, with regard to the first shaft gear 31-1 and the third shaft gear 31-3 of the shaft gears 31, the shaft gears 31 are fixed to the fixation position of the shaft gears 31 (i.e., the position located on the upper side in Fig. 2) indicated by the solid line in the gear fixation portion 14e of Fig. 2. On the other hand, with respect to the second shaft gear 31-2 and the fourth shaft gear 31-4, the shaft gears 31 are fixed to the fixation position of the shaft gears 31 (i.e., the position located on the lower side in Fig. 2) indicated by the imaginary line in the gear fixation portion 14e of Fig. 2.

Moreover, as shown in Fig. 3, the rotating unit 30 located on the left-hand side in the figure is provided with two cogged belts 32 of a first cogged belt 32-1 arranged on the left-hand side in the figure and a second cogged belt 32-2 arranged on the right-hand side in the figure. The first cogged belt 32-1 and the second cogged

belt 32-2 are engaged with one driving gear 33 by the inner peripheral surfaces thereof. Further, the first cogged belt 32-1 is engaged with the first shaft gear 31-1 and the third shaft gear 31-3 by the inner peripheral surface thereof, while the second cogged belt 32-2 is engaged with the second shaft gear 31-2 and the fourth shaft gear 31-4 by the inner peripheral surface thereof.

As shown in Fig. 1, the driving gear 33 has teeth 33a, which are formed vertically in two rows so as to be engageable with the respective cogged belts 32. An upper row side driving gear 33b, which is located on the upper row side of the two rows, is engaged with the first cogged belt 32-1, while a lower row side driving gear 33c, which is located on the lower row side, is engaged with the second cogged belt 32-2. That is, as shown in Fig. 1, the first cogged belt 32-1 and the second cogged belt 32-2 have a relation of mutually vertical arrangement. The first cogged belt 32-1 is arranged on the upper side in the figure, and the second cogged belt 32-2 is arranged on the lower side in the figure, so that the cogged belts 32 do not interfere with each other. It is to be noted that the first shaft gear 31-1, the third shaft gear 31-3 and the upper row side driving gear 33b are arranged at same height of placement, while the second shaft gear 31-2, the fourth shaft gear 31-4 and the lower row side driving gear 33c are

arranged at same height of placement. Therefore, the first cogged belt 32-1 and the second cogged belt 32-2, which have the aforementioned mutually vertical arrangement, are arranged roughly parallel to each other.

Moreover, as shown in Fig. 3, a tension roller 35-1 is provided between the first shaft gear 31-1 and the driving gear 33 so as to consistently urge the first cogged belt 32-1 toward the inside thereof, consistently applying a constant tension force to the first cogged belt 32-1 for the retention of a firm engagement relation among the first shaft gear 31-1, the third shaft gear 31-3, the upper row side driving gear 33b and the first cogged belt 32-1. Likewise, a tension roller 35-2 is provided between the fourth shaft gear 31-4 and the driving gear 33 so as to consistently urge the second cogged belt 32-2 toward the inside thereof, consistently applying a constant tension force to the second cogged belt 32-2 for the retention of a firm engagement relation among the second shaft gear 31-2, the fourth shaft gear 31-4, the lower row side driving gear 33c and the second cogged belt 32-2.

As shown in Figs. 1, 2 and 3, a rotational driving force or the tension force is applied to the shaft gears 31 by the cogged belts 32. However, the first outer cylinder collar 14, which fixes the shaft gears 31 and is surely supported by the bearing sections 51 and 53 at both

upper and lower ends of the gear fixation portion 14e, therefore scarcely receives the influence of the rotational driving force or the tension force.

With the rotating unit 30 having the above-mentioned structure, by rotatively driving the rotating drive motor 34 in either the forward or reverse rotational direction, the driving gears 33 are rotatively driven in the above-mentioned rotational direction via the driving shaft 34a, and the first cogged belt 32-1 engaged with the upper row side driving gear 33b and the second cogged belt 32-2 engaged with the lower row side driving gear 33c are concurrently driven to run along the above-mentioned rotational direction. By this operation, the first shaft gear 31-1 and the third shaft gear 31-3 engaged with the first cogged belt 32-1 are concurrently driven to rotate in the above-mentioned rotational direction, while the second shaft gear 31-2 and the fourth shaft gear 31-4 engaged with the second cogged belt 32-2 are concurrently driven to rotate in the above-mentioned rotational direction. As a result, in the shaft sections 10 (one example of the first shaft section through the fourth shaft section) corresponding to the four shaft gears 31, the first spline nut 12 and the second spline nut 13 are rotatively driven around the respective axes R of rotation via the respective first outer cylinder collars 14 fixed to the respective

shaft gears 31, allowing the respective spline shafts 11 to concurrently rotate around the axes R of rotation.

(Regarding the Elevation Unit)

The structure of the elevation unit 20 will be described in detail next. It is to be noted that the eight elevation units 20 provided for the head section 100 have similar structures. Therefore, in the following description of the elevation units 20, the structure of one elevation unit 20 out of these elevation units will be described unless specially mentioned.

First of all, as shown in Fig. 1, the elevation unit 20 is provided with a ball screw shaft 21 that is one example of the ball screw shaft section supported by the elevation frame 42 provided for the head frame 40 rotatably around the axis S of rotation arranged roughly parallel to the axis R of rotation of the spline shaft 11. The elevation unit 20 is further provided with an elevation drive motor 22 that is one example of the rotating drive section, which is fixed to the upper end portion in the figure of the ball screw shaft 21 and rotates the ball screw shaft 21 in either the forward or reverse rotational direction around the axis S of rotation, and an elevation nut section 23, which is meshed with the ball screw shaft 21 and moved up and down along the axis S of rotation by the rotation of the ball screw shaft 21. Moreover, the

elevation unit 20 is further provided with an elevation bar 24 that is one example of the engagement member formed of a roughly L-figured rigid body, which has one end fixed to the elevation nut section 23 and is moved up and down integrally with the ascent and descent of the elevation nut section 23. Moreover, the elevation bar 24 is arranged so that the end portion 24a, which is the other end of this elevation bar 24, is engaged with the upper portion of the spline shaft 11 via two bearing sections 25 fixed apart from each other to the upper portion of the spline shaft 11. Moreover, the end portion 24a of this elevation bar 24 has a roughly U-figured shape. The end portion 24a of the elevation bar 24 and the outer ring portion of the two bearing sections 25 are fixed to each other so as to hold the two bearing sections 25 inside the roughly U-figured shape, the engagement of the elevation bar 24 with the spline shaft 11 is achieved. Moreover, the two bearing sections 25 are fixed to the upper portion of the spline shaft 11 by its inner ring portion, and therefore, the engagement of the elevation bar 24 with the spline shaft 11 does not hinder the rotation of the spline shaft 11 around the axis R of rotation.

Moreover, as shown in Fig. 1, an annular spring receiving section 26 is fixed to the lower surface of the bearing section 25 located on the lower side in the figure

among the two bearing sections 25 fixed to the spline shaft 11, and the upper end of a spring 27 arranged in an annular shape on the outer periphery of the spline shaft 11 is attached to the lower end of this spring receiving section 26. Further, as shown in Fig. 1, an annular stepped portion 14f is formed on the inner peripheral surface of the gear fixation portion 14e of the first outer cylinder collar 14 of the shaft section 10, and the lower end of the spring 27 is attached to this stepped portion 14f.

This spring 27 plays a role of supporting the spline shaft 11 supported by the first spline nut 12 and the second spline nut 13 elevatably along the axis R of rotation so that the spline shaft does not fall due to its own weight or the like and consistently urging upward the spline shaft 11 so as to put the engagement positions of the elevation bar 24 and the spline shaft 11 into a state in which they are more securely retained.

With the elevation unit 20 having the above-mentioned structure, the elevation nut section 23 meshed with the ball screw shaft 21 can be moved up or down along the axis S of rotation by driving the elevation drive motor 22 to rotate in either the forward or reverse the rotational direction to rotate the ball screw shaft 21 around the axis S of rotation in the rotational direction. Further, the elevation bar 24 fixed to this elevation nut

section 23 is to be moved up or down along the axis S of rotation together with the elevation nut section 23. Due to the engagement of this elevation bar 24 with the spline shaft 11, the spline shaft 11 can be moved up or down along the axis R of rotation in synchronization with the ascent or descent of the elevation nut section 23. This spline shaft 11 is moved up or down along the inner peripheral surfaces of the first spline nut 12 and the second spline nut 13. It is to be noted that the amount of ascent or descent of the elevation nut section 23 can directly be the amount of ascent or descent of the spline shaft 11 by the state of secure engagement of the end portion 24a of the elevating bar 24 with the spline shaft 11. That is, by controlling the rotational drive amount of the elevation drive motor 22, the amount of elevation of the spline shaft 11 can be controlled. It is to be noted that the end portion 24a of the elevation bar 24, which is to move up and down the spline shaft 11 via the bearing section 25 located on the lower side, exerts no influence on the rotational operation of the spline shaft 11.

Moreover, when the ball screw shaft 21 is rotated around the axis S of rotation thereof by the rotatively driven elevation drive motor 22 in each elevation unit 20, the elevation nut section 23 receives a rotation moment around the axis S of rotation, and the elevation bar 24

fixed to this elevation nut section 23 also similarly receives a rotation moment. In the above-mentioned case, due to the fact that the end portion 24a of the elevation bar 24 has the roughly U-figured shape, this rotation moment is to be transmitted to the spline shaft 11 via each bearing section 25. This spline shaft 11, which is formed so as to have rigidity resistible to this rotation moment, is able to restrict the rotation around the axis S of rotation of the elevation bar 24 and the elevation nut section 23. Therefore, the elevation bar 24 and the elevation nut section 23 have their movement in the rotational direction consistently restricted only by the engagement of the elevation bar 24 with the spline shaft 11, and the elevation nut section 23 can be moved up and down along the axis S of rotation by the rotation of the ball screw shaft 21.

(Assembling Procedure of the Shaft Section)

The procedure for assembling the components in the shaft section 10 of the head section 100 having the above-mentioned construction will be described next.

First of all, in Fig. 2, the first nut fixation portion 14a of the first outer cylinder collar 14 is fastened and fixed to the outer peripheral surface of the first spline nut 12 in the state in which the first spline nut 12 and the second spline nut 13 areassembled to the

spline shaft 11, and the second nut fixation portion 15a of the second outer cylinder collar 15 is similarly fastened and fixed to the outer peripheral surface of the second spline nut 13. Further, the inner peripheral surface of the intermediate collar 16 is bonded and fixed to each of the portion of the outer peripheral surface of the first spline nut 12 exposed from the first outer cylinder collar 14 and to the outer peripheral surface of the second spline nut 13 exposed from the second outer cylinder collar 15, joining the first spline nut 12 to the second spline nut 13.

As described above, the first support portion 14b located in the position where the first outer cylinder collar 14 is supported by the bearing section 51 and the second support portion 15b located in the position where the second outer cylinder collar 15 is supported by the bearing section 52 are concurrently processed in a state in which the spline shaft 11, the first spline nut 12, the second spline nut 13, the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are assembled together. The nozzle attaching portion 11a, which is the portion to be detachably equipped with the suction nozzle 2, of the spline shaft 11 is concurrently processed. Further, the upper support portion 14d located in the position (also the upper end portion of the first outer cylinder collar 14) where the first outer

cylinder collar 14 is supported by the bearing section 53 is also concurrently processed. The processing of the above-mentioned portions is carried out in a state in which the spline shaft 11 is rotated around the axis R of rotation so that the axes of rotation of the above-mentioned portions coincide with the axis R of rotation of the spline shaft 11 by, for example, finely cutting the outer peripheral surface and the end portions of the above-mentioned portions.

After effecting the processing as described above, the shaft gear 31 is inserted into and fixed to the gear fixation portion 14e of the first outer cylinder collar 14, and this assembly is inserted into the shaft frame 41 in a state in which the spline shaft 11, the first spline nut 12, the second spline nut 13, the first outer cylinder collar 14, the second outer cylinder collar 15, the intermediate collar 16 and the shaft gear 31 are assembled together. The shaft section 10 is supported by the shaft frame 41 via the bearing sections 51, 52 and 53. The shaft section 10 can be thus assembled and supported by the shaft frame 41. Moreover, with regard to the production accuracy (i.e., allowance limits of error of the design dimensions and work dimensions) of the components in the shaft section 10, the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are produced

within an accuracy of about 20 μm. As a result of effecting the processing in the state in which the components produced with the above-mentioned production accuracy are assembled together, a misalignment (i.e., concentricity) of the axis R of rotation of the spline shaft 11 with respect to the support sections of the bearing sections 51, 52 and 53 can be restrained to about 10 to 30 μm.

The shaft gear 31 is to be fixed to the gear fixation portion 14e of the first outer cylinder collar 14 by its inner peripheral surface. The concentricity of the axis of rotation of the shaft gear 31 with respect to the axis R of rotation of the spline shaft 11 can be within a dimensional error of about 20 μm in terms of the production accuracy with respect to the inner peripheral surface of the shaft gear 31 and the gear fixation portion 14e of the first outer cylinder collar 14.

(Regarding the Component Placing Operation by the Head Section)

Next, the operation of sucking and holding the electronic component 1 by the head section 100, which having the aforementioned construction is attached to the X-Y robot of the aforementioned electronic component placing apparatus (not shown), and place the electronic component 1 sucked and held to the mounting position of the

component 1 on the circuit board held on the machine base in the electronic component placing apparatus will be described next.

First of all, the head section 100 is moved along the surface of the circuit board by the X-Y robot so that the suction nozzles 2 of the head section 100 are located above an electronic component supply section in which a plurality of electronic components 1 are ejectably supplied in the electronic component placing apparatus.

Subsequently, in each of the elevation units 20 of the head section 100 of Fig. 1, the elevation drive motor 22 is rotatively driven in either the forward or reverse rotational direction with its rotational drive amount controlled, moving down the elevation nut section 23 along the axis S of rotation via the ball screw shaft 21. By this operation, the elevation bar 24 is moved down in each of the elevation units 20, depressing downward the bearing section 25 engaged with its end portion 24a. By this operation, the spring 27 is contracted, and the spline shaft 11 is moved down along the axis R of rotation while being slid on the inner peripheral surface of the first spline nut 12 and the second spline nut 13. In each of the shaft sections 10, the end portion of the suction nozzle 2 comes in contact with the upper surface of the electronic component 1, and the suction nozzle 2 sucks and holds the

electronic component 1. Subsequently, in each of the elevation units 20, the rotational direction of the elevation drive motor 22 is reversed, and the elevation bar 24 is moved up. In accordance with the ascent of this elevation bar 24, the spline shaft 11 is moved up along the axis R of rotation, and the electronic component 1 sucked and held by the suction nozzle 2 is moved up and taken out of the electronic component supply section. At this time, since the spline shaft 11 is consistently urged upward by the spring 27 in each of the elevation units 20, the spline shaft 11 is moved up while the position of elevation of the spline shaft 11 is restricted by the end portion 24a of the elevation bar 24.

There may be either the case where the suction nozzles 2 are concurrently moved up and down in the head section 100 to suck and hold and take out the electronic components 1 or the case where the suction nozzles 2 are successively moved up and down to suck and hold and take out the electronic components 1.

Subsequently, the head section 100 is moved by the X-Y robot upwardly of the circuit board in the electronic component placing apparatus. In this movement process, by picking up the image of the electronic components 1 sucked and held by the suction nozzles 2 of the head section 100 (by picking up the image by, for

example, a camera provided for the machine base of the electronic component placing apparatus or a camera provided for the head section 100 (neither one is shown) or the like), the sucked-and-held posture of the electronic component 1 by each of the suction nozzles 2 is recognized. On the basis of the recognition result of each sucked-and-held posture, the sucked-and-held posture is corrected so that the sucked-and-held posture coincide with the placed posture (posture of placement in the placement position), and the electronic components 1 are to be placed in the respective placement positions on the circuit board.

For example, a displacement in the rotational direction around the axis R of rotation may occur between the sucked-and-held posture and the placement posture of the electronic component 1. In such a case, the displacement can be corrected (hereinafter referred to as a θ correction) by rotatively moving (i.e., rotating by an angle of θ) the suction nozzle 2 around the axis R of rotation.

The procedure for executing the θ correction in the head section 100 will be described in concrete. First of all, the θ correction is executed sequentially from the electronic component 1 sucked and held by the suction nozzle 2 that firstly performs the placing operation of the electronic component 1 among the eight suction nozzles 2

provided for the head section 100. For example, when the shaft gear 31 attached to the shaft section 10 equipped with this suction nozzle 2 is the shaft gear 31-1 shown in Fig. 3, the rotating drive motor 34 in the rotating unit 30 located on the left-hand side in the figure is first rotatively driven in either the forward or reverse rotational direction with its rotational drive amount controlled on the basis of the rotational angle to be subjected to the θ correction, driving the first cogged belt 32-1 to run along the rotational direction via the upper row side driving gear 33b. By this operation, the first shaft gear 31-1 is rotated by the rotational angle in the rotational direction around the axis of rotation thereof. At this time, due to the structure of the rotating unit 30, the second shaft gear 31-2, the third shaft gear 31-3 and the fourth shaft gear 31-4 are concurrently rotated by the same rotational angle in the same rotational direction.

In accordance with the above-mentioned rotation of the first shaft gear 32-1, the first outer cylinder collar 14 integrally fixed to the gear fixation portion 14e to the inner peripheral surface of the first shaft gear 32-1 is rotatively driven. Further, the first outer cylinder collar 14, the second outer cylinder collar 15, the intermediate collar 16, the first spline nut 12 and the

second spline nut 13, which are put in a mutually integrated state, are rotatively driven around the axis R of rotation, and the spline shaft 11 is also rotated around the axis R of rotation by the aforementioned angle in the rotational direction. By this operation, the suction nozzle 2 equipped for the nozzle attaching portion 11a of the spline shaft 11 is rotatively moved around the axis R of rotation by the aforementioned rotational angle, effecting the θ correction of the electronic component 1.

At this time, as described above, the nozzle attaching portion 11a, the first support portion 14b, the second support portion 14c and the upper support portion 14d are concurrently processed in the state in which the spline shaft 11, the first spline nut 12, the second spline nut 13, the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are assembled together. Therefore, the concentricity of the axes of rotation is improved, and the θ correction can be executed with high accuracy.

In the rotating unit 30, the suction nozzle 2 by which the placing operation of the electronic component 1 is executed next, i.e., one shaft gear 31 is selected from among the second shaft gear 31-2, the third shaft gear 31-3 and the fourth shaft gear 31-4, and the θ correction is executed according to a similar procedure.

Moreover, as shown in Fig. 3, the head section 100 is provided with the two rotating units 30 that have the same structure. Therefore, the θ correction can be concurrently executed also in the rotating unit 30 located on the right-hand side in the figure while executing the θ correction in the rotating units 30 located on the left-hand side in the figure. By thus concurrently executing the θ correction in the head section 100, the time for executing the θ correction for all the suction nozzles 2 can be reduced.

Subsequently, the positional alignment of the suction nozzle 2 by which the placing operation is performed first among the suction nozzles 2 provided for the head section 100 with the placement position of the circuit board is carried out by the X-Y robot. After the positional alignment, the elevation drive motor 22 is driven to rotate in either the forward or reverse rotational direction with its rotational drive amount controlled in the elevation unit 20 corresponding to the suction nozzle 2, moving down the elevation nut section 23 along the axis S of rotation via the ball screw shaft 21. By this operation, the elevation bar 24 is moved down to depress downward the bearing sections 25 engaged with the end portion 24a thereof. By this operation, the spring 27 is contracted, and the spline shaft 11 is moved down along

the axis R of rotation while being slid on the inner peripheral surfaces of the first spline nut 12 and the second spline nut 13. Subsequently, the lower surface of the electronic component 1 held by the suction nozzle 2 comes in contact with the placement position of the circuit board. In the placement position of the circuit board, a bonding material of solder or the like is preparatorily supplied, and the lower surface of the electronic component 1 is further pressed against the bonding material. In this state, the descent by the elevation unit 20 is stopped, and the sucking and holding of the electronic component 1 by the suction nozzle 2 is released. Subsequently, the spline shaft 11 is moved up by the elevation unit 20 to move up the suction nozzle 2, and the electronic component 1 is placed in the placement position of the circuit board. Subsequently, operation similar to the above will be repetitively executed for the other suction nozzles 2 to place the respective electronic components 1 on the circuit board.

The operation of placing a plurality of electronic components 1 on the circuit board can be thus executed by the head section 100.

In this case, Fig. 7 shows a schematic sectional view of part of a head section 200 according to a modification example of the head section of the present

first embodiment, and the structure of a portion to be joined to the elevation unit and the spline shaft will be described in detail with reference to Fig. 7. It is to be noted that the basic structure of the head section 200 described below is roughly similar to that of the head section 100 shown in Fig. 1, and the detailed structural section is more concretely shown. Moreover, similarly to the head section 100, the head section 200 is provided with eight spline shafts (or suction nozzles) and eight elevation units corresponding independently to the spline shafts. However, since they have a mutually identical structure, the relation between one set of spline shafts and the elevation units thereof will be explained in the following description.

As shown in Fig. 7, the elevation unit 220 provided for the head section 200 is provided with a ball screw shaft 221 that is one example of the ball screw shaft section rotatably supported by an elevation frame 242 around the axis S of rotation (the H shaft) arranged in the same direction (i.e., the perpendicular direction) as that of the axis R of rotation of the spline shaft 211. In concrete, the ball screw shaft 221 provided with the axial center thereof as the axis S of rotation has its both end portions fixed to the elevation frame 242 (by using, for example, a fixing nut section 261 or the like) via bearing

sections (only the bearing section 262 for fixing the end portion on the upper side is shown in the figure). Moreover, the end portion on the upper side of the ball screw shaft section 221 is joined to an elevation drive motor 222 via a coupling 260. By being rotatively driven around the axis S of rotation as a consequence of the transmission of the rotating drive by this elevation drive motor 222 to the ball screw shaft 221 via the coupling 260, an elevation nut section 223 meshed with the ball screw shaft 221 can be moved up and down. Moreover, the elevation unit 220 is provided with an elevation bar 224, which has one end fixed to the elevation nut section 223 and is one example of the engagement member formed of a rigid body having a roughly L-figured shape moved up and down integrally with the ascent and descent of the elevation nut section 223. Moreover, this elevation bar 224 is formed by fastening a joint bracket-B 224b that is the one end fixed to the elevation nut section 223 to a joint bracket-A 224a engaged with the spline shaft 211 by means of, for example, screwing.

Moreover, as shown in Fig. 7, the spline shaft 211, of which the axial center is arranged so as to roughly coincide with its axis R of rotation, is rotatably supported by a head frame (not shown) via (first and second) spline nuts. The upper end side of the spline

shaft 211 is the portion to be engaged with the joint bracket-A 224a, and the engagement between the joint bracket-A 224a and the spline shaft 211 is achieved via a bearing section-A 225A and a bearing section-B 225B attached to the outer periphery of the spline shaft 211.

More in detail, the end portion of the joint bracket-A 224a has a roughly ring-like shape. By fixing the roughly ring-shaped inside of the joint bracket-A 224a to the outer ring portions of the bearing section-A 225A and the bearing section-B 225B so that the bracket hold both the bearing section-A 225A and the bearing section-B 225B inside the roughly ring-like shape, the aforementioned engagement is achieved. Moreover, the inner ring portions of the bearing section-A 225A and the bearing section-B 225B are fixed to the outer peripheral surface of the spline shaft 211, and a spacer 263 that is arranged so as to bury the inner ring portions of the bearing sections is further fixed to the outer peripheral surface of the spline shaft 211. It is to be noted that a gap is provided between the joint bracket-A 224a and the spacer 263, the gap assuring no contact between them.

Moreover, an annular spring receiving section 226 is fixed to the lower portion of the inner ring of the bearing section-B 225B, and the upper end of the spring 227 is attached to the lower end of this spring receiving

section 226. It is to be noted that the lower end of the spring 227 is attached to an annular stepped portion formed on the inner peripheral surface of the gear fixation portion of the first outer cylinder collar of a shaft section (not shown). With the above-mentioned spring 227 or the like provided, the spline shaft 211 whose own weight is supported by the elevation unit 220 via the elevation bar 224 is supported by the spring 227 instead of the support by the elevation unit 220 when, for example, electrification to the elevation drive motor 222 of the elevation unit 220 is interrupted (e.g., during power failure or the like), allowing this spline shaft 211 to be prevented from falling. The reason why the joint bracket-A 224a and the joint bracket-B 224b are fastened to each other by screwing in the elevation bar 224 is for fine adjustment of the positions of the axes R and S of rotation in the head section 200.

Moreover, an upper shaft 265 is arranged above the spline shaft 211 on the axis R of rotation, and a lower portion of this upper shaft 265 is integrally fixed to the upper end of the spline shaft 211 by fastening by screwing or the like. Moreover, a metal bearing section 264 for guiding the ascent and descent of the upper shaft 265, which is moved up and down integrally with the spline shaft 211, is formed on the left-hand side in the figure in the

upper portion of the elevation frame 242. Moreover, an air joint 266, which is the joined portion to be joined to a vacuum unit, is provided at the upper end of the upper shaft 265. The upper shaft 265 and the spline shaft 211 have hollow holes, which are both formed along the respective axial centers and mutually communicating, allowing vacuum to reach the end of the suction nozzle from the vacuum unit via the air joint 266 and the hollow holes and allowing the end portion of the suction nozzle to suck and hold an electronic component.

According to the construction and function of the above-mentioned head section 200, the elevation nut section 223 can be moved up and down in the elevation unit 220 by rotatively driving the elevation drive motor 222 and rotating the ball screw shaft 221 around the axis S of rotation via the coupling 260. With the ascent of this elevation nut section 223, the elevation bar 224 fixed to the elevation nut section 223 is also moved up and down integrally with the elevation nut section 223, and the elevating operation of the spline shaft 211 along the axis R of rotation can be performed via the bearing section-A 225A and the bearing section-B 225B.

In this elevating operation, the elevation nut section 223 is to receive a reactive force generated when the ball screw shaft 221 is rotated by the elevation drive

motor 222. In the conventional construction of the elevation unit that employs a ball screw shaft and an elevation nut section, there is the general practice of restricting (guiding) the pivot by the reactive force of the elevation nut section by using an LM guide (e.g., LM guide 526 of Fig. 4) or the like in order to resist such a reactive force. In contrast to this, the embodiment of the present modified example adopts a structure that employs the two bearing sections of the bearing section-A 225A and the bearing section-B 225B in the upper portion of the spline shaft 211, providing a construction resisting the reactive force by the spline shaft 211 itself. With this arrangement, the LM guide, which has been employed in the conventional construction, is made unnecessary. This allows the gap between the spline shaft 211 and the ball screw shaft 221 (i.e., the gap between the axis R of rotation and the axis S of rotation) can be shortened, allowing the downsizing of the head section 200 to be achieved.

Moreover, in the construction of the above-mentioned present embodiment, the spline shaft 211 is required to have a mechanical rigidity sufficient for resisting the reactive force. The required mechanical rigidity is sometimes higher than the mechanical rigidity required for mounting an electronic component with high

accuracy. Therefore, the present embodiment contributes to the substantial improvement of the rigidity of the spline shaft 211 by providing the metal bearing section 264 for elevatably supporting (guiding) the upper shaft 265 integrated with the spline shaft 211 without increasing the diameter of the spline shaft 211. There can be considered a technique for providing one more set of spline nuts for elevatably rotatably supporting the spline shaft 211 instead of the above-mentioned technique for improving the rigidity. However, this technique has a problem that the spline shaft 211 is sometimes unable to move up and down or rotate when its axial center is slightly displaced with respect to the axis R of rotation due to the reactive force received by the spline shaft 211, errors in producing and assembling the spline shaft and the like, and therefore, it cannot be said that this technique is a preferable technique. In the present embodiment, for example, a gap of about 30 to 50 μm is provided between the metal bearing section 264 and the peripheral surface of the upper shaft 265 in order to prevent in advance the occurrence of the above-mentioned problem in the metal bearing section 264.

(Effects of the First Embodiment)

According to the aforementioned first embodiment, the following various effects can be obtained.

First of all, the first outer cylinder collar 14

and the second outer cylinder collar 15 are fixed by the first nut fixation portion 14a and the second nut fixation portion 15a, respectively, to the outer peripheral surface of the first spline nut 12 and the second spline nut 13 that are arranged apart each other in each of the shaft sections 10 of the head section 100 and are able to elevatably support the spline shaft 11 along the axis R of rotation, and the inner peripheral surface of the intermediate collar 16 is bonded and fixed. With this arrangement, the two spline nuts of the first spline nut 12 and the second spline nut 13 can be joined to each other and put in an integrated body.

Further, the two spline nuts put in the integrated body can be rotatably supported around the axis R of rotation by the shaft frame 41 via the two bearing sections 51 and 52 in the first support portion 14b of the first outer cylinder collar 14 and the second support portion 15b of the second outer cylinder collar 15. That is, the two spline nuts can be rotatably supported by the two bearing sections 51 and 52, and the amount of bearing sections to be placed for supporting the spline nuts in each of the shaft sections 10 can be reduced.

For example, although each of the shaft section 510 is provided with two spline nuts similarly to the head section 100 of the first embodiment in the conventional

head section 500, the four bearing sections are attached to support the two spline nuts. However, in the head section 100 of the first embodiment, the amount of bearing sections to be placed can be reduced, and this allows the assembling of the shaft sections 10 in the head section 100 to be facilitated and allows the production cost of the head section 100 to be reduced. Moreover, since the amount of bearing sections to be placed is also reduced, the positional alignment of the axes R of rotation of the spline shafts 11 with the axis of rotation of the bearing sections (also the axes of rotation of the first outer cylinder collar 14 and the second outer cylinder collar 15 in the first embodiment) can be facilitated (i.e., the places to be subjected to the positional alignment can be reduced). Therefore, the quantity of displacement due to the rotation of the suction nozzle 2 in the shaft section 10 can be reduced, and the rotational accuracy can be improved.

Moreover, instead of supporting the spline nuts directly by the outer peripheral surfaces thereof by the shaft frame 41 via the bearing sections, the stepped portion 14c is formed between the first support portion 14b and the first nut fixation portion 14a so that the outside diameter of the portion 14b becomes approximately equal to or preferably smaller than the inside diameter of the

portion 14a in the first outer cylinder collar 14, and the stepped portion 15c is formed between the second support portion 15b and the second nut fixation portion 15a so that the outside diameter of the portion 15b similarly becomes approximately equal to or preferably smaller than the inside diameter of the portion 15a in the second outer cylinder collar 15. By supporting the two spline nuts via the first support portion 14b, the second support portion 15b and the two bearing sections 51 and 52, the inside diameter of the bearing sections can be made approximately equal to or smaller than the outside diameter of the spline nuts while reducing the amount of the bearing sections to be placed.

As described above, when the inside diameter of the bearing section can be reduced, the outside diameter of each shaft section 10 can be reduced, and the arrangement interval between the spline shafts 11 provided for the head section 100 can be narrowed, allowing a downsized head section 100 to be provided.

Conversely, when the outside diameter of the shaft section 10 is not reduced, the outside diameter of the spline shaft 11 can be increased without changing the outside diameter of the shaft section 10, and the rigidity of the spline shaft 11 can be improved. In such a case, the generation of the displacement or the like of the axis

R of rotation of the spline shaft 11 can be restrained by the rigidity even when, for example, an external force is applied to the spline shaft 11 during the replacement of the suction nozzle 2 or another case, and a head section having a higher rotational accuracy can be provided.

Moreover, by cutting the outer peripheral surfaces of the first support portion 14b in the position where the first outer cylinder collar 14 is supported by the bearing 51, the second support portion 15b in the position where the second outer cylinder collar 15 is supported by the bearing 52 and the upper support portion 14d in the position where the first outer cylinder collar 14 is supported by the bearing section 53 while rotating the spline shaft 11 around the axis R of rotation in the state in which the spline shaft 11, the first spline nut 12, the second spline nut 13, the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are integrally assembled in attaching each of the shaft section 10 to the head section 100, the axis of rotation of the portions that have undergone the machining can be made to roughly coincide with the axis of rotation of the spline shaft 11 with high accuracy. Furthermore, the shaft section 10 can be rotatably supported by the shaft frame 41 via the bearing sections 51, 52 and 53 by inserting the shaft section 10

assembled in the above-mentioned state into the shaft frame 41, and a head section 100 having a high rotational accuracy can be provided.

As a concrete example, although the components of the shaft section 510 are produced with a production accuracy of about 10 μm in the conventional head section 500, the displacement of the axes of rotation further occurs during assembly, and a concentricity of about 50 μm to 70 μm is achieved after the assembling. On the other hand, in the head section 100 of the first embodiment, the cutting is carried out after the components are assembled even if the first outer cylinder collar 14, the second outer cylinder collar 15 and the intermediate collar 16 are produced with a production accuracy of about 20 μm. Therefore, a concentricity of about 10 to 30 μm can be finally obtained.

Moreover, dissimilarly to the conventional case where the shaft gear is attached to the outer cylinder collar 516 via the coupling 535 in each of the shaft sections 10, the shaft gear 31 is directly fixed to the gear fixation portion 14e of the first outer cylinder collar 14 in the state in which the concentricity is improved as described above. Therefore, the concentricity of the axis of rotation of the shaft gear 31 with respect to the axis R of rotation of the spline shaft 11 can be

improved.

Moreover, dissimilarly to the conventional case where the four shaft gears 531 are engaged with one another inside the one cogged belt 532 in each of the rotating units, the first cogged belt 32-1 and the second cogged belt 32-2 are provided as the two cogged belts in each of the rotating units 30, the first cogged belt 32-1 is engaged with the first shaft gear 31-1 and the third shaft gear 31-3, and the second cogged belt 32-2 is engaged with the second shaft gear 31-2 and the fourth shaft gear 31-4. Therefore, the areas of engagement of the four shaft gears 31 can be uniformed in the state in which the areas of engagement of the cogged belts with the shaft gears 31 are sufficiently secured. With this arrangement, the deviation in the rotational accuracy, which has been generated by the deviation in the area of engagement, can be canceled. Further, by sufficiently securing the areas of engagement, each of the shaft gears 31 can reliably be driven to rotate, and the suction nozzles 2 can be rotated with high rotational accuracy.

As a concrete example, in contrast to the fact that the rotational accuracy of the θ-rotation by the rotating unit 530 is about 0.2 degrees in the conventional head section 500, the rotational accuracy of the θ-rotation by the rotating unit 30 can be improved to 0.01 degrees or

less in the head section 100 of the first embodiment.

In each of the elevation units 20, the movement of the elevation bar 24 and the elevation nut section 23 in the rotational direction thereof is consistently restricted by only the engagement between the elevation bar 24 and the spline shaft 11, and the elevation nut section 23 can be moved up and down along the axis S of rotation by the rotation of the ball screw shaft 21. However, the above-mentioned structure can be provided by forming large the outside diameter of the spline shaft 11 by the support structure with the outside diameters of the bearing sections 51 and 52 maintained in the shaft section 10 for the improvement of the rigidity (i.e., strength) as described by the aforementioned effects. Therefore, in the support structure in which the outside diameter of the spline shaft 511 cannot be formed large (i.e., for the reason that the entire head section becomes disadvantageously large if the external shape is formed large) as in the conventional head section 500, the LM guide 526, which has been needed to receive the rotation moment transmitted from the elevation nut section 523 to the spline shaft 511 via the elevation bar 524, can be made unnecessary in the head section 100 of the first embodiment. With this arrangement, the dimension between the axis R of rotation of the spline shaft 11 and the axis S of rotation

of the ball screw shaft 21 can be reduced by obviating the need for the LM guide, and a head section 100 further reduced in size can be provided. For example, the aforementioned dimension can be reduced by about 30 to 40 mm in comparison with that of the conventional head section.

(Second Embodiment)

The present invention is not limited to the aforementioned embodiment but able to be provided in a variety of embodiments. For example, Fig. 8 shows a schematic sectional view of a head section 300 that is one example of the component placing head according to the second embodiment of the present invention.

As shown in Fig. 8, the head section 300 basically has a structure similar to that of the head section 100 of the first embodiment shown in Fig. 1. Therefore, the components having structures similar to those described above are denoted by the same reference numerals as in Fig. 1, and no description is provided therefor. Moreover, in the description of the construction and functions of the following head section 300, the construction and functions of the elevation unit 20 that has characteristic construction and actions in the present second embodiment will be described more in detail than in the first embodiment.

As shown in Fig. 8, in the elevation unit 20 of

the head section 300, the axis S of rotation of the axial center of the ball screw shaft 21 is assumed as an elevating operation axis, and the elevation nut section 23 is moved up and down along the elevating operation axis, and the elevating operation range is restricted between an upper end position and a lower end position. In concrete, the elevation nut section 23 can be moved up and down along the axis S of rotation between an upper end side restriction frame 43 that is one example of the restricting portion fixed and attached to the elevation frame 42 in an upper portion of the ball screw shaft 21 (below the elevation drive motor 22) and a lower end side restriction frame 44 that is one example of the restricting portion fixed and attached to the elevation frame 42 in a lower portion of the ball screw shaft 21. Moreover, by bringing the upper end of the elevation nut section 23 being moved upward in contact with the lower end of the upper end side restriction frame 43, the upward movement of the elevation nut section 23 is restricted in this position of contact. Moreover, by bringing the lower end of the elevation nut section 23 being moved downward in contact with the upper end of the lower end side restriction frame 44, the downward movement of the elevation nut section 23 in this position of contact is restricted.

Moreover, each of the elevation units 20 provided

for the head section 300 is provided with an encoder 71 that is one example of the rotational angle detecting section capable of detecting the rotational angle around the axis S of rotation of the elevation drive motor 22. In each of the elevation units 20, the encoder 71 can detect a relative rotational angle with respect to the origin of rotation by setting one point of the rotational angle as the origin of rotation. Moreover, the variation of this rotational angle has a relation proportional to the amount of rotation of the ball screw shaft 21 and the amount of elevating operation of the elevation nut section 23.

Further, each of the elevation units 20 is provided with an overload detecting section 72 capable of detecting the overload of the elevation drive motor 22. In each of the elevation units 20, the overload detecting section 72 can detect the overload of the elevation drive motor 22 when, for example, the upper end of the elevation nut section 23 comes in contact with the upper end side restriction frame 43 and this position of elevation is limited while the elevation drive motor 22 attempts to perform the rotational driving.

(Regarding the Light Transmission Unit)

In the head section 300 that has the above-mentioned construction, the elevation units 20 move up and down the suction nozzles 2 along the axes R of rotation via

the respective spline shafts 11 in the shaft sections 10, thereby carrying out the sucking and taking-out operation and the placing operation of electronic components 1. During these operations, it is important which height position the suction nozzle 2 is moved up from and which height position the suction nozzle 2 is moved down to along the axis R of rotation thereof. Therefore, each of the elevation units 20 that carry out the elevating operation can execute origin detecting operation (this origin detecting operation will be described later) for detecting the origin position that becomes a reference height position of the elevating operation. By executing the above-mentioned origin detecting operation periodically or arbitrarily in the head section 300, the reliable elevating operation of each of the suction nozzles 2 in the head section 300 is guaranteed.

The head section 300 is provided with a light transmission unit 60 that executes part of the above-mentioned origin detecting operation, and the structure of this light transmission unit 60 will be described.

As shown in Fig. 8, the light transmission unit 60 is provided with a light-projecting section 61 and a light-receiving section 62, which are arranged opposite to each other, in a direction along the array direction of the ball screw shafts 21, and the light-projecting section 61

and the light-receiving section 62 are attached and fixed to the elevation frame 42 so that the ball screw shafts 21 thereof are arranged between the light-projecting section 61 and the light-receiving section 62. Figs. 9A through 9D are explanatory views schematically showing the origin detecting operation (method) in the head section 300. As shown in Fig. 9A, the light-projecting section 61 and the light-receiving section 62 are provided on the elevation frame 42 (not shown in Figs. 9A through 9D) with the relations of arrangement thereof maintained. Moreover, the light-projecting section 61 can irradiate light from a light-emitting section 61a provided on the light-receiving section 62 side of the light-projecting section 61 toward the light-receiving section 62, while the light-receiving section 62 can receive and detect the light emitted from the light-projecting section 61 in a light-detecting section 62a provided on the light-projecting section 61 side of the light-receiving section 62. Moreover, as shown in Figs. 9A through 9D, an optical axis T is arranged between the light-emitting section 61a and the light-detecting section 62a so that the light, which is emitted from the light-emitting section 61a and received and detected by the light-detecting section 62a, is roughly parallel to the array direction of the ball screw shafts 21 and roughly perpendicular to the axis S of rotation of each

of the ball screw shafts 21.

Figs. 10A through 10C show schematic explanatory views of the elevation unit 20, viewed in the direction of arrow A in Figs. 9A through 9D. As shown in Fig. 10A, the optical axis T located between the light-detecting section 62a and the light-emitting section 61a (not shown in Figs. 10A through 10C) in the light transmission unit 60 is arranged on the left-hand side in the figure without interfering with the ball screw shafts 21. Moreover, as shown in Fig. 10B or 10C, when the elevation nut section 23 is moved down along the ball screw shaft 21, the left-hand portion in the figure of the elevation nut section 23 can interfere with the optical axis T.

With the optical axis T thus arranged, when at least one elevation nut section 23 among the elevation nut sections 23 provided for the head section 300 is located in a position where the nut section interferes with the optical axis T by the elevating operation thereof (e.g., in the state of Fig. 10B or 10C), the light emitted from the light-projecting section 61 is interrupted by at least one elevation nut section 23 and not received by the light-receiving section 62. Conversely, when all the elevation nut sections 23 in the head section 300 are located in positions where the nut sections do not interfere with the optical axis T by the elevating operation thereof (e.g., in

the state of Fig. 10A), the light emitted from the light-projecting section 61 is received by the light-receiving section 62 while being interrupted by none of the elevation nut sections 23.

In this case, the height position along the elevating operation axis (also the axis S of rotation) of the elevation nut section 23 in each of the elevation units 20 of the head section 300 will be described with reference to the schematic explanatory view shown in Fig. 11. It is to be noted that each of the height positions shown in Fig. 11 is the position at the lower end of the elevation nut section 23. Since the elevation units 20 provided for the head section 300 perform similar elevating operation, one elevation unit 20 out of the elevation units 20 will be described with reference to Fig. 11.

As shown in Fig. 11, the elevation nut section 23 can move up and down between an upper end position of the elevating operation at a height of H = +2 mm and a lower end position of the elevating operation at a height of H = -65 mm with respect to the axial origin (H = 0 mm) that is the origin of elevation served as a reference height position. Moreover, the optical axis T of the light transmission unit 60 is located at a height of H = -7 mm. The optical axis T is arranged so that the optical axis T does not interfere with the elevation nut section 23 in the

state in which the lower end position of the elevation nut section 23 is located at the height of H = -6 mm, and the optical axis T interferes with the elevation nut section 23 in the state in which the lower end position of the elevation nut section 23 is located at the height of H = -8 mm.

In the present specification, a "prescribed light interruption dimension" is assumed to mean a dimension (i.e., 7 mm) from the axial origin (H = 0 mm) to the height position (H = -7 mm) where the optical axis T is arranged. However, taking the arrangement error of the height position of the optical axis T, the production error of the elevation nut section 23 and so on into consideration, it is preferable to set the prescribed light interruption dimension slightly greater than the aforementioned dimension to set the height position where the interruption of light is reliably detected. In the present embodiment, the dimension is set within the height position of H = -8 mm (i.e., 8 mm).

Moreover, the height position relation of the elevation nut section 23 is synchronized with the height position relation of the spline shaft 11 and the suction nozzle 2 corresponding to this elevation nut section 23. For example, the height position of H = -63 mm is the nozzle replacement height of the suction nozzle 2 equipped

for the nozzle attaching portion 11a of the spline shaft 11. By the elevating operation of the elevation nut section 23 mainly within a height position range of H = 0 mm to H = -63 mm, the placing operation of the electronic component 1 is executed by the corresponding suction nozzle 2.

In each of the elevation units 20, the variation in the rotational angle of the elevation drive motor 22 detected by the encoder 71 and the amount of the elevating operation of the elevation nut section 23 are in a proportional relation, and the origin of rotation of the rotational angle can be detected at a 12 mm pitch with respect to the position of H = 0 mm served as the reference position. That is, the origin of rotation can be detected by the encoder 71 at each of the height positions of H = 0, 12, 24, 36, 48 and 60 mm.

(Regarding the Control Section)

Next, the control section for controlling the operations in the head section 300 will be described next. As shown in Fig. 8, the head section 300 is provided with a control section 9 that controls the sucking and holding operation of the electronic component 1 by each of the suction nozzles 2, the elevating operation in each of the elevation units 20 and the rotational operation in each of the rotating units 30. This control section 9 controls each of the suction nozzles 2, each of the elevation units

20 and each of the rotating units 30 so that the operations thereof are related to one another, thereby enabling the placing operation of the electronic component 1 in the head section 300.

Moreover, the control section 9 is provided with an origin detection control section 8 that can control the origin detecting operation (method) for detecting the origin position of elevation of the elevation nut section 23 of each of the elevation units 20 in the head section 300. The detailed origin detecting operation in the origin detection control section 8 will be described later. Moreover, as shown in Fig. 8, this origin detection control section 8 can receive inputs of the detection's result (i.e., a rotational angle detection signal and an overload detection signal) from the encoder 71 and the overload detecting section 72 provided for each of the elevation units 20. Moreover, emission of light and the presence or absence of interruption of light of the emitted light in the light transmission unit 60 are inputted as detection signals to the origin detection control section 8, and the origin detection control section 8 can determine the presence or absence of the interruption of light.

(Regarding the Origin Detecting Operation)

A method for detecting the origin of the elevating operation of the elevation nut section 23 in each

of the elevation units 20 in the head section 300 that has the aforementioned construction and function will be described next. Figs. 12 and 13 show a flowchart representing this origin detecting operation, and description is made on the basis of this flowchart. Each action of this origin detecting operation is controlled by the origin detection control section 8 of the control section 9.

First of all, as shown in Fig. 9A, in each of the elevation units 20, the elevation drive motor 22 is driven to rotate, moving up the elevation nut section 23 located in an arbitrary height position on the elevating operation axis on the elevating operation axis (step S1 in the flowchart of Fig. 12). The elevated elevation nut section 23 has its upper end brought in contact with the upper end side restriction frames 43, and this event of contact is determined by detecting the overload of the elevation drive motor 22 by the overload detecting section 72 and inputting this detection result to the origin detection control section 8 (step S2). It is to be noted that the ascent of the elevation nut section 23 is effected until this overload detection is performed. Moreover, the height position where this overload detection is performed is a position of H = +2 mm in Fig. 4, and this state is the state shown in Fig. 9B. Fig. 9B shows the state in which

the contact is made only in the elevation nut section only 23 located at the left-hand end in the figure.

When this overload is detected, then the rotational direction of the elevation drive motor 22 is reversed (step S3). By this operation, the elevation nut section 23 is moved down along the elevating operation axis (step S4). During this descent, the origin of rotation of the elevation drive motor 22 is detected by the encoder 71, and the descent is effected until the origin of rotation is detected. When the origin of rotation is detected by the encoder 71 (step S5), the rotational driving of the elevation drive motor 22 is stopped, and the descent of the elevation nut section 23 is stopped. Further, the stop position of the elevation nut section (position at the lower end) on this elevating operation axis is set as an origin of elevation (i.e., set as an origin presumed to be the axial origin (this is hereinafter assumed to be the detection origin)) in the origin detection control section 8, and setting is performed assuming that the elevation nut section 23 is located at the height position of H = 0 mm in Fig. 11 (step S6).

The actions from the step S1 to the step S6 may be either in the case where the actions are executed concurrently in the elevation units 20 of the rotating unit 30 or in the case where the actions are executed

sequentially. Subsequently, the detection origin is set in every elevation nut section 23 provided for the head section 300, and the origin detection control section 8 confirms the state of stop of the elevation nut sections 23 at the set detection origins (step S7). When there is an elevation nut section 23 that is not stopped at the detection origin with regard to the elevation nut sections 23, the actions from the step S1 to the step S6 are executed for the elevation nut section 23 (step S8). Moreover, the state in which all the elevation nut sections 23 provided for the head section 300 are stopped at the respective detection origins is shown in Figs. 9C and 10A.

After confirming that all the elevation nut sections 23 are stopped at the respective detection origins in the origin detection control section 8, one elevation nut section 23 is selected from among all the elevation nut sections 23 (step S9 in the flowchart of Fig. 13), and the selected elevation nut section 23 starts to move down from the detection origin (step S10). This descent is effected by detecting the rotational angle of the elevation drive motor 22 by the encoder 71 in a state in which the descent height position on the elevating operation axis is recognized by the origin detection control section 8.

Subsequently, when the origin detection control section 8 determines that the lower end of the selected

elevation nut section 23 is moved down to the position of H = -6 mm in Fig. 11, the origin detection control section 8 detects the presence or absence of the interruption of light emitted from the light-projecting section 61 toward the light-receiving section 62 of the light transmission unit 60 (step S11). When the interruption of light is not confirmed in step S11, the selected elevation nut section 23 is not stopped, and the descent is continuously effected. Subsequently, when it is determined that the lower end of the selected elevation nut section 23 is moved down to the position of H = -8 mm in Fig. 11, i.e., moved down by the light interruption prescribed dimension in the origin detection control section 8, the origin detection control section 8 detects the presence or absence of the interruption of light emitted from the light-projecting section 61 toward the light-receiving section 62 of the light transmission unit 60 (step S12). When the interruption of light is confirmed in step S12, the origin detection control section 8 determines that the detection origin coincides with the axial origin with regard to the selected elevation nut section 23 (step S13). The irradiation of light by the light transmission unit 60 is only required to be effected at least in accordance with the timing of the step S11 and the step S12, and this may be performed either in the case where the irradiation of

light is continuously effected in advance or in the case where the irradiation of light is intermittently effected in accordance with the above-mentioned timing. Moreover, the state of the elevation nut section 23 in step S12 is the state shown in Figs. 9D and 10B. Fig. 9D shows a state in which the elevation nut section 23 located secondly from the left-hand side in the figure of each of the elevation nut sections 23 provided for the head section 300 is moving down.

Moreover, when the interruption of light is detected by the origin detection control section 8 in step S11, the lower end of the selected elevation nut section 23, which is estimated to be moved down to the position of H = -6 mm, is interfering with the optical axis T of the light transmission unit 60 located at the position of H = -7 mm shown in Fig. 11. This is interpreted as the incorrect detection of the detection origin and as the occurrence of a detection origin setting error (step S16).

Likewise, when the interruption of light is not detected by the origin detection control section 8 in step S12, the lower end of the selected elevation nut section 23, which is estimated to be moved down to the position of H = -8 mm, is not interfering with the optical axis T of the light transmission unit 60 located in the position of H = -7 mm shown in Fig. 11. This is interpreted as the

incorrect detection of the detection origin and as the occurrence of a detection origin setting error (step S16).

The selected elevation nut section 23, which has undergone confirmation of the detection origin in step S13 is moved up to the detection origin position (step S15), and the next one elevation nut section 23, which has not yet been selected, is selected from among the elevation nut sections 23 provided for the head section 300 (step S17). Subsequently, the procedure from the step S10 to the step S14 is similarly executed for this selected next one elevation nut section 23. In step S15, when the origin detection control section 8 determines that the coincidence of the detection origins of all the elevation nut sections 23 provided for the head section 300 with the axial origins has been confirmed, this origin detecting operation is completed.

In the above description, the origin detecting operation is executed for all the elevation nut sections 23 provided for the head section 300. However, the origin detecting operation is not limited only to the above-mentioned case, and there may be the case where the origin detecting operation is executed for only one elevation nut section 23. In such a case, if it is confirmed in step S15 that the confirmation of the axial origin has been executed for the elevation nut section 23 to be subjected to the

origin detection, then the origin detecting operation ends.

Moreover, in the flowchart of the origin detecting operation shown in Figs. 12 and 13, a series of operation from the step S1 to the step S8 is one example of the origin setting means (or origin setting process), and a series of operation from the step S9 to the step S17 is one example of the origin confirming means (or origin confirming process).

Although the aforementioned origin detecting operation has been executed by concurrently using the encoder 71 and the overload detecting section 72 provided for each of the elevation units 20 for the setting of the detection origins according to the above description, the second embodiment is not limited to this case. For example, in place of the above-mentioned case, the overload detecting section 72 may not be provided since the setting of the origin detection can be performed when the position of elevation on the elevating operation axis of the elevation nut section 23 can be detected only by the detection of the rotational angle of the elevation drive motor 22 by the encoder 71.

Moreover, in the present second embodiment, the origin detecting operation is executed by detecting that the light emitted from the light transmission unit 60 is interrupted directly by each of the elevation nut sections

23. Each of the elevation nut sections 23 is formed with a production dimension accuracy of, for example, about ±0.05 mm, by which the origin detection accuracy of the origin detecting operation can be within a range of about ±0.2 mm, and this allows reliable accurate origin detection to be achieved.

(Suction Nozzle Interference Prevention Interlock)

Interference prevention interlock of the suction nozzle 2 utilizing the light transmission unit 60 provided for the aforementioned head section 300 will be described next.

As shown in Figs. 8 and 11, each of the elevation nut sections 23 provided for the head section 300 has its elevating operation upper end position mechanically restricted by the upper end side restriction frame 43 and has its lower end position mechanically restricted by the lower end side restriction frame 44. As shown in Fig. 11, with regard to each of the elevation nut sections 23, its height position along the elevating operation axis (i.e., the axis S of rotation) is elevatable within a range in which H = +2 mm to -65 mm. Moreover, the optical axis T of the light transmission unit 60 has its height position set at H = -7 mm, and the interruption of light is detected when arbitrary portions of the elevation nut section 23, including its lower portion, is located at the height

position of H = -7 mm.

When the elevation height position of each of the elevation nut sections 23 is located on the lower side of the position of H = -7 mm, the interruption of light can surely be detected by the light transmission unit 60 by using the function of the aforementioned light transmission unit 60. In concrete, each of the elevation nut sections 23 is formed so that the upper portion of each of the elevation nut sections 23 interferes with the optical axis T located in the position of H = -7 mm in a state in which each of the elevation nut sections 23 is located in the elevating operation lower end position (H = -65 mm). With this arrangement, when each of the elevation nut section 23 is consistently interfering with the optical axis T of the light transmission unit 60 when located below the position of H = -7 mm, and the interference of light is to be detected.

By thus forming each of the elevation nut sections 23, when one elevation nut section 23 among the elevation nut sections 23 provided for the head section 300 is located below the position of H = -7 mm, i.e., when the suction nozzle 2 corresponding to the elevation nut section 23 is located in the height position below the position of H = -7 mm, the interference of light is surely detected by the light transmission unit 60. By inputting this

detection result to the control section 9 via the origin detection control section 8, the control section 9 inhibits the movement of the main body of the head section 300 along the surface of the circuit board (i.e., the movement carried out by the X-Y robot provided for the electronic component placing apparatus), enabling the prevention of the interference of the suction nozzle 2 located in the aforementioned lower height position with the constituent members of the electronic component placing apparatus, the electronic components 1 and the like mounted on the circuit board. That is, the detection of light by the light transmission unit 60 can be the interference prevention interlock of the suction nozzles 2 in the head section 300.

(Effects of the Second Embodiment)

According to the second embodiment, the following various effects can be obtained.

First of all, instead of performing the mounting operation of the electronic components 1 by executing the elevating-operation of each of the suction nozzles 2 in the head section 300 using this detection origin as it is after the detection origin of elevation of each of the elevation nut sections 23 is set by detecting the origin of rotation of each of the elevation drive motors 22 by means of each of the encoders 71 provided for the head section 300, it is confirmed whether or not these set detection origins

actually coincide with the axial origins. Therefore, even if a malfunction (setting error) occurs during the setting of each of the detection origins, the setting error can reliably be detected, and the possible occurrence of a placement error due to the fact that the detection origin does not coincide with the axial origin can be prevented in advance in the subsequent placing operation of the electronic components 1, and reliable origin detection can be achieved. This allows the electronic component placing operation to be achieved with high accuracy in the component placing apparatus provided with the aforementioned head section 300.

Moreover, the aforementioned origin detection can be achieved by providing the head section 300 with only one light transmission unit 60, which is provided with the light-projecting section 61 and the light-receiving section 62 arranged opposite to each other along the array direction of the ball screw shafts 21, allowing the elevation nut sections 23 to be arranged between the light-projecting section 61 and the light-receiving section 62, and detecting the presence or absence of the interruption of the light by the elevation nut section 23 by receiving the light emitted from the light-projecting section 61 toward the light-receiving section 62 by the light-receiving section 62.

That is, by the operation that the interruption of light is not detected, by the light transmission unit 60, in which the height position of the optical axis T of the emission of light thereof is set to H = -7 mm, when one elevation nut section 23 is selected from among the elevation nut sections 23 in the state in which they are located in the respective set detection origin positions, the selected elevation nut section 23 is moved down with respect to the set detection origin as a reference, and the lower end of the selected elevation nut section 23 is moved down to the height position of H = -6 mm. And the operation that the interruption of light is detected by the light transmission unit 60 when the lower end is moved down to the height position of H = -8 mm, the origin detection control section 8 determines that the set detection origin coincides with the axial origin of this elevation nut section 23, allowing the origin detection to be achieved. Moreover, for the other elevation nut sections 23, the origin detection can be achieved by confirming that the set detection origins coincide with the respective axial origins according to a similar procedure through successive selection.

Therefore, even when a plurality of, for example, eight suction nozzles 2 are provided as in the head section 300, the confirmation of the origin can be achieved by

providing one light transmission unit 60 for the head section 300 without providing each of the elevation units 20 with a unit for the origin confirmation. Therefore, the head section capable of executing reliable origin detection can be provided with a simple construction, and the production cost thereof can be suppressed low.

Moreover, the light transmission unit 60 can detect whether or not the light emitted from the light-projecting section 61 is directly interrupted by the elevation nut section 23. The construction of the head section can be made simple without providing a special light shield plate (e.g., DOG etc.) for the interruption of the light, and this can contribute to the downsizing of the head section.

Moreover, by providing each of the elevation units 20 of the head section 300 with the overload detecting section 72 in addition to the encoder 71, it is determined that the elevation nut section 23 has been moved up and the elevation nut section 23 has come in contact with the upper end side restriction frame 43 by the detection of the overload of the elevation drive motor 22 by the overload detecting section 72 during the setting of the detection origin of each of the elevation nut sections 23. When this detection is performed, the elevation drive motor 22 is reversed to move down the elevation nut section

23, and after the initiation of this descent, the lowered position of the elevation nut section 23 when the origin of rotation of the elevation drive motor 22 detected first by the encoder 71 is detected can be set as the detection origin position. With this arrangement, the setting of the detection origin can be achieved with the simple construction of the encoder 71 and the overload detecting section 72 providing neither complicated mechanism nor unit for this detection origin setting for the head section 300.

Moreover, in the case where each of the elevation nut sections 23 provided for the head section 300 has its elevation height position located on the lower side of the position of H = -7 mm, when one elevation nut section 23 among the elevation nut sections 23 is located in the position of H = -7 mm, i.e., when the suction nozzle 2 corresponding to the elevation nut section 23 is located in the height position lower than the position of H = -7 mm with the formation such that the interruption of light is surely detected by the light transmission unit 60, the interruption of light can surely be detected by the light transmission unit 60. By inputting this detection result to the control section 9 via the origin detection control section 8, the control section 9 inhibits the movement of the main body of the head section 300 along the surface of the circuit board (i.e., the movement carried out by the X-

Y robot provided for the electronic component placing apparatus), enabling the prevention of the interference of the suction nozzle 2 located in the aforementioned lower height position with the constituent members of the electronic component placing apparatus, the electronic components 1 and the like mounted on the circuit board. That is, the detection of light by the light transmission unit 60 can further be the interference prevention interlock of the suction nozzle 2 in the head section 300, and this can obviate the need for providing a special sensor or the like for the provision of the interlock like this in the head section 300, allowing the construction of the head section to be simple.

It is to be noted that, by appropriately combining arbitrary embodiments of the aforementioned embodiments, the effects possessed by them can be produced.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.